OCTOBER 1956

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 48 • NO. 10

Two Parts
Part 1: Part 2 is AWWA Directory

Reorganization at Philadelphia	Baxter, Arnold
Meters and Metering	Kuranz, Smith, Barrett
Domestic Service Requirements	Carns
Results of Cloud-seeding Experiments	Krick
Taste and Odor Control	Ettinger, Middleton
Corrosion Problems	Larson, Skold, Savinelli, Sudrabin
Toxicity of Cadmium and Chromium	Decker, Hoppert, Byerrum
Limits for Coliform Organisms	Walton
In-Service Training	Dann, Shull, Van Heuvelen, LaLonde
Financing Suburban Extensions	Rigling
Disinfection With Ozone	Hann
Detection of Surfactants	Rosen, Middleton, Taylor
Experiences With 'Standard Methods'	Derby, Taras
Interference Organisms in Indiana Waters	Palmer, Poston

Reduce Wear, Save Time and Money with Mathews Flange Barrel Hydrant

The Mathews Flange Barrel Hydrant is designed to deliver every available gallon of water and to last indefinitely with minimum maintenance. Check these important features:

The Flange Barrel

The swivel flange at the base of the nozzle section permits nozzles to be faced toward any point in the complete circle. Saves time on original installation and on replacements.

On broken hydrants, top cap and nozzle sections can usually be salvaged, thus reducing accident costs.

The Stuffing Box Plate

Cast integral with the nozzle section, the plate keeps water and sediment away from the operating thread. Hydrant remains operable in any weather. Wear on the operating thread is largely eliminated.

Breakable Flange and Stem Coupling

Optional feature furnished at extra cost. Specially designed flange in the standpipe just above ground level and a frangible coupling in the hydrant stem are designed to snap when struck a blow heavy enough to break the hydrant. Both can be replaced quickly *and without excavating*, while hydrant head, standpipe and stem remain undamaged.

ADDITIONAL ADVANTAGES

Two-way heads can be replaced with steamer and two-way heads without shutting off the water supply.

Shield operating nut protects revolving nut from sleet, snow or dust.

An extension piece may be inserted between hydrant head and barrel or between barrel and elbow.

Available with mechanical joint pipe connections.

Made by R. D. WOOD COMPANY

Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Journal

AMERICAN WATER WORKS ASSOCIATION

2 PARK AVE., NEW YORK 16, N.Y. • Phone: MUrray Hill 4-6686

October 1956

Vol. 48 • No. 10

Two Parts
PART 1

Part 2 is
AWWA Directory

Contents

Management Reorganization of Philadelphia Water Department...SAMUEL S. BAXTER 1199
Universal Metering and Meter Repair at Philadelphia.....GERALD E. ARNOLD 1209
Practical Metering Procedure at Waukesha.....JOSEPH H. KURANZ 1217
Water Metering for Increased Revenue.....WENTWORTH SMITH 1227
New Algicides..... 1234
Galvanic Corrosion in Water Meters.....HERBERT F. BARRETT 1235
Service Line and Meter Requirements of Domestic Water-connected Devices
JAMES G. CARNS JR. 1243
Results of Cloud-seeding Operations to Augment Municipal Supplies
IRVING P. KRICK 1250
Plant Facilities and Human Factors in Taste and Odor Control
MORRIS B. ETTINGER & FRANCIS M. MIDDLETON 1265
Tuberculation of Tar-coated Cast Iron in Great Lakes Water
THURSTON E. LARSON, R. V. SKOLD & E. SAVINELLI 1274
Report on Toxicity Studies of Cadmium and Chromium
CLARENCE F. DECKER, C. A. HOPPERT & R. U. BYERRUM 1279
Relation of Treatment Methods to Limits for Coliform Organisms in Raw Waters
GRAHAM WALTON 1281
In-Service Training Program of the Philadelphia Suburban Water Company
GEORGE H. DANN & KENNETH E. SHULL 1290
Training Water Works Personnel
Objectives and Techniques.....W. VAN HEUVELEN 1295
In-Service Programs.....LAWRENCE E. LALONDE 1297
External-Corrosion Problems in the Water Distribution System....LEON P. SUDRABIN 1301
Financing Suburban Extensions.....VANCE F. RIGLING 1311
Disinfection of Drinking Water With Ozone.....VICTOR A. HANN 1316
Identification of Anionic Synthetic Detergents in Foams and Surface Waters
AARON A. ROSEN, FRANCIS M. MIDDLETON & NEIL W. TAYLOR 1321
Experiences With the Tenth Edition of *Standard Methods*.....RAY L. DERBY 1331
Discussion.....MICHAEL J. TARAS 1334
Algae and Other Interference Organisms in Indiana Water Supplies
C. MERVIN PALMER & H. WALLACE POSTON 1335

Departments

Officers and Directors..... *2 P&R*
Coming Meetings..... *8 P&R*
Percolation and Runoff..... *35, 80 P&R*
Condensation..... *62 P&R*
New Members..... *96 P&R*
Index of Advertisers' Products... *100 P&R*

HARRY E. JORDAN, *Secretary*
ERIC F. JOHNSON, *Asst. Secy.—Publications*
LAWRENCE FARBER, *Managing Editor*
DONALD A. NELSEN, *Assistant Editor*
ALBERT NEWGARDEN, *Assistant Editor*

Journal AWWA is published monthly at Prince & Lemon Sts., Lancaster, Pa., by the Am. Water Works Assn., Inc., 2 Park Ave., New York 16, N.Y., and entered as second class matter Jan. 23, 1943, at the Post Office at Lancaster, Pa., under the act of Aug. 24, 1912. Accepted for mailing at a special rate of postage provided for in paragraph (d-2), Section 34.40, P. L. & R. of 1948. Authorized Aug. 6, 1918. $7.00 of members' dues are applied as a subscription to the JOURNAL; additional single copies to members—60 cents; single copies to non-members—85 cents. Indexed annually in December; and regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm edition (for JOURNAL subscribers only) by University Microfilms, Ann Arbor, Mich.

© 1956, by the American Water Works Association, Inc. Made in U.S.A.

AWWA Officers and Directors

President	PAUL WEIR	*Past-President*	F. C. AMSBARY JR.
Vice-President	FRED MERRYFIELD	*Treasurer*	WILLIAM W. BRUSH
Ch. W.W. Practice Com.	LOUIS R. HOWSON	*Secretary*	HARRY E. JORDAN
Ch. W.W. Admin. Com.	WENDELL R. LADUE	*Exec. Asst. Secretary*	RAYMOND J. FAUST
Ch. Publication Com.	E. SHAW COLE	*Asst. Secretary-Pub.*	ERIC F. JOHNSON

Officers of the Sections

Section	*Director*	*Chairman*	*Vice-Chairman*	*Secretary-Treasurer*
Alabama-Miss.	E. M. Stickney	W. U. Quinby	H. L. Burns	Irving E. Anderson
Arizona	Dario Travaini	M. V. Ellis	Q. M. Mees	H. C. Bigglestone
California	B. S. Grant	W. R. Seeger	M. J. Shelton	H. J. Ongerth
Canadian	C. G. R. Armstrong	V. A. McKillop	H. P. Stockwell	A. E. Berry
Chesapeake	David Auld	B. L. Werner	R. W. Haywood	C. J. Lauter
Cuban	G. A. Bequer H.	J. A. Vila	M. F. DeVera	L. H. Daniel
Florida	W. W. Gillespie	J. R. Kelly	Stanley Sweeney	J. D. Roth
Illinois	E. E. Alt	G. L. Davis	C. L. Baylor	D. W. Johnson
Indiana	C. E. Williams	C. E. Robbins	R. G. Rinehart	R. J. Becker
Iowa	C. W. Hamblin	D. L. Bragg	P. H. Morgan	J. J. Hail
Kansas	H. W. Badley	B. H. Van Blarcum	R. F. Bluejacket	H. W. Badley
Kentucky-Tenn.	Elmer Smith	J. J. Davis	R. A. Fischer	J. Wiley Finney Jr.
Michigan	E. D. Barrett	C. R. Erickson	W. E. Smith	T. L. Vander Velde
Missouri	H. O. Hartung	E. G. Lee	F. J. McAndrew	W. A. Kramer
Montana	C. W. Eyer	B. F. Chestnut	R. G. Cronin	A. W. Clarkson
Nebraska	Bert Gurney	C. L. Fisher	George Beard	J. E. Olsson
New England	E. S. Chase	J. H. Robinson	F. J. Thiery	J. E. Revelle
New Jersey	C. J. Alfke	Maurice Brunstein	H. M. Ohland	C. B. Tygert
New York	J. G. Copley	F. D. Behan	L. J. Griswold	Kimball Blanchard
North Carolina	W. M. Franklin	R. S. Phillips	C. W. Mengel	W. E. Long Jr.
North Central	L. N. Thompson	L. H. Coult	H. H. Behlmer	L. N. Thompson
Ohio	C. E. Beatty	D. D. Heffelfinger	M. W. Tatlock	M. E. Druley
Pacific Northwest	E. J. Alien	C. R. Harlock	H. J. Donnelly	Fred D. Jones
Pennsylvania	L. D. Matter	B. F. Johnson	G. E. Arnold	L. S. Morgan
Rocky Mountain	G. J. Turre	J. O. Jones	Harry Barnes	J. W. Davis
Southeastern	Sherman Russell	C. C. Lanford	L. E. Wallis	N. M. deJarnette
Southwest	J. R. Pierce	J. H. O'Neill	H. R. Street	L. A. Jackson
Virginia	E. C. Meredith	H. F. Knoell	W. W. Anders	J. P. Kavanagh
West Virginia	W. S. Staub	C. B. Whitlock	C. C. Coffield	H. W. Hetzer
Wisconsin	J. C. Zufelt	B. J. Hartman	J. E. Kerslake	Harry Breimeister

Directors Representing the Water and Sewage Works Manufacturers Assn.

CARL N. BROWN ROBERT F. ORTH R. S. RANKIN

Officers of the Divisions

Division	*Chairman*	*Vice-Chairman*	*Secretary*
Water Distribution	H. W. Niemeyer	E. J. Allen	J. B. Ramsey
Water Purification	H. H. Gerstein	P. D. Haney	Sherman Russell
Water Resources	H. C. Barksdale	C. H. Bechert	J. W. Cramer
Water Works Management	L. W. Grayson	W. W. DeBerard	J. D. Kline

TO THE ENDS OF THE EARTH...

From Canada to South Africa—
from the Pacific Ocean to the Near East—
Lock Joint Concrete Pressure Pipe
continues unfailingly to bring life-giving water
to cities, farms and industries.

Engineers and water works officials
of many countries have shopped the world and, like
so many of their fellow experts in the United States,
have chosen Lock Joint Concrete Pressure Pipe
as the most durable, dependable and
economical medium for the construction of their
vital water supply and distribution lines.

You cannot do better than to follow
their example and specify LOCK JOINT.

LOCK JOINT PIPE CO.

East Orange, New Jersey

Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn. • Kansas City, Mo.
Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

LIST OF ADVERTISERS

	P&R PAGE
Ace Pipe Cleaning, Inc.	80
AG Chemical Co.	—
Alabama Pipe Co.	—
Alco Products, Inc.	91
Allis-Chalmers	86, 87
American Agricultural Chemical Co.	90
American Brass Co., The	28
American Cast Iron Pipe Co.	—
American Concrete Pressure Pipe Assn.	69
American Cyanamid Co., Heavy Chemicals Dept.	94
American Pipe & Construction Co.	9
American Well Works	95
Anthracite Equipment Corp.	—
Armco Drainage & Metal Products, Inc.	14
Badger Meter Mfg. Co.	92, 93
Barrett Div.	21
Bethlehem Steel Co.	26
B-I-F Industries, Inc.	19, 74
Buffalo Meter Co.	27
Builders-Providence, Inc. (Div., B-I-F Industries)	19, 74
Byron Jackson Div., Borg-Warner Corp.	—
Calgon, Inc.	16
Carborundum Co., The	101
Carson, H. Y., Co.	82
Carus Chemical Co.	70
Cast Iron Pipe Research Assn., The	64, 65
Centriline Corp.	—
Chain Belt Co.	25
Chapman Valve Mfg. Co.	54
Chicago Bridge & Iron Co.	—
Clow, James B., & Sons	15, 41
Cochrane Corp.	—
Cole, R. D., Mfg. Co.	76
Crane Co.	—
Darley, W. S., & Co.	70
Darling Valve & Mfg. Co.	—
De Laval Steam Turbine Co.	45
DeZurik Shower Co.	—
Dorr-Oliver Inc.	Cover 3
Dresser Mfg. Div.	77
du Pont, I. E., de Nemours & Co.	52
Eddy Valve Co.	15, 41
Electro Rust-Proofing Corp.	—
Ellis & Ford Mfg. Co.	48
Everson Mfg. Corp.	—
Filtration Equipment	84
Fischer & Porter Co.	47
Flexible Inc.	—
Ford Meter Box Co., The	66, 67
Foster Engineering Co.	38
Foxboro Co.	—
Frontier Chemical Co.	—
General Chemical Div., Allied Chemical & Dye Corp.	18
General Filter Co.	53
Golden-Anderson Valve Specialty Co.	88
Graver Water Conditioning Co.	—
Greenberg's, M., Sons	—
Hammarlund Mfg. Co.	—
Hammond Iron Works	97
Harco Corp.	—
Hays Mfg. Co.	81
Hersey Mfg. Co.	17
Hungerford & Terry, Inc.	72
Hydraulic Development Corp.	31
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	33
Inertol Co., Inc.	—
Infilco Inc.	37
Iowa Valve Co.	15, 41
Johns-Manville Corp.	6, 7
Johnson, Edward E., Inc.	—
Jones, John Wiley, Co.	29
Keasbey & Mattison Co.	73
Kennedy Valve Mfg. Co., The	—
Klett Mfg. Co.	100
Koppers Co., Inc.	11
LaMotte Chemical Products Co.	68
Layne & Bowler, Inc.	99
Leadite Co., The	Cover 4
Leopold, F. B., Co.	50
Limitorque Corp.	46
Lock Joint Pipe Co.	3
Ludlow Valve Mfg. Co.	42
M & H Valve & Fittings Co.	23
Millipore Filter Corp.	—
Minneapolis-Honeywell Regulator Co.	103
Monolith Portland Midwest Co.	—
Mueller Co.	49
National Cast Iron Pipe	15, 41
National Water Main Cleaning Co.	61
Neptune Meter Co.	34
Northern Gravel Co.	98
Omega Machine Co. (Div., B-I-F Industries)	—
Pekrul Gate Div. (Morse Bros. Machinery Co.)	—
Permutit Co.	12, 13
Phelps Dodge Refining Corp.	—
Philadelphia Gear Works, Inc.	46
Philadelphia Quartz Co.	40
Pittsburgh-Des Moines Steel Co.	24
Pittsburgh Equitable Meter Div. (Rockwell Mfg. Co.)	108
Pollard, Jos. G., Co., Inc.	75
Portland Cement Assn.	—
Pratt, Henry, Co.	—
Proportioneers, Inc. (Div., B-I-F Industries)	—
Reed Mfg. Co.	20
Reilly Tar & Chemical Corp.	105
Rensselaer Valve Co.	43
Roberts Filter Mfg. Co.	—
Rockwell Mfg. Co.	108
Ross Valve Mfg. Co.	—
Schleicher, Carl, & Schuell	—
Simplex Valve & Meter Co.	78, 79
Skinner, M. B., Co.	48
Smith, A. P., Mfg. Co., The	71
Smith, S. Morgan, Co.	30
Smith-Blair, Inc.	—
Sparton Control Systems	51
Spring Load Mfg. Corp.	—
Steel Plate Fabricators Assn.	39
Stuart Corp.	—
Tennessee Corp.	22
Trinity Valley Iron & Steel Co.	85
U.S. Pipe & Foundry Co.	5
Wachs, E. H., Co.	—
Walker Process Equipment, Inc.	—
Wallace & Tiernan Inc.	32
Well Machinery & Supply Co.	89
Western Materials Co.	—
Wheeler, C. H., Mfg. Co.	83
Wood, R. D., Co.	Cover 2
Woodward Iron Co.	107
Worthington-Gamon Meter Div.	63

Directory of Professional Services—pp. *55-60 P&R*

Giant helicopters . . . atomic-powered and capable of lifting vast tonnages . . . some day may transport homes intact from winter to summer locations . . enable people to move with a minimum of disorder and effort.

100 years from now...

WE MAY MOVE HOUSES BY AIR!

Many incredible changes in the world of tomorrow. But even then, our water and gas will still be carried by that dependable public servant—the cast iron pipe being laid today.

Records show that cast iron mains installed over a hundred years ago are still serving effectively for more than seventy American water and gas utilities. Moreover, the modernized cast iron pipe of today . . . centrifugally cast and quality controlled . . . is even stronger, tougher, more serviceable.

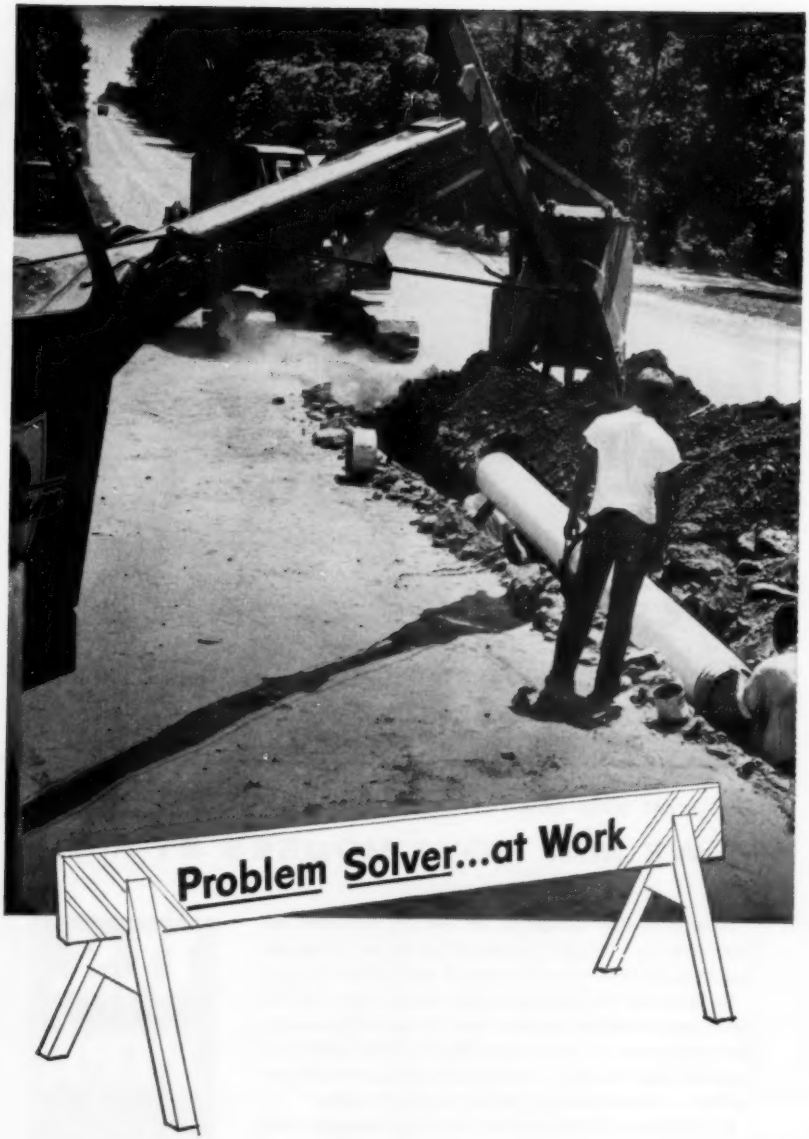
U.S. Pipe is proud to be one of the leaders in a forward-looking industry whose service to the world is measured in centuries.

U.S. cast iron PIPE

CAST IRON

U. S. PIPE AND FOUNDRY COMPANY, General Office: Birmingham 2, Alabama

A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE.



Johns-Manville

Transite Pressure Pipe assures dependable service through the years

ENGINEERS and city officials face much the same problem in pipe selection. It is twofold: (1) How to make sure the community gets many long years of trouble-free performance from its pressure mains, and (2) How to do this as economically as possible by choosing pipe for durability plus savings.

Transite® Pressure Pipe is solving this problem in hundreds of municipalities and water districts from coast to coast. Here's why. An asbestos-cement product, strong and durable and highly resistant to corrosion, it has effected economies in installation as well as operation.

For example, the community benefits even at the very outset, since both handling and assembly of Transite Pressure Pipe are so simple that crews can install as fast as trench is opened. This means lower installed costs.

Another Transite Pipe characteristic instantly recognized by engineers as of major importance is its smooth interior that stays smooth. This provides maintained high flow capacity. (Flow coefficient is C = 140.)

For further information about Transite Pressure Pipe with the Ring-Tite® Coupling, write for Booklet TR-160A. Address Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

TRANSITE PRESSURE PIPE
with the RING-TITE Coupling

JOHNS-MANVILLE JM PRODUCTS

Plan now for

AWWA ANNUAL CONFERENCE

Atlantic City, N.J. May 12-17, 1957

Coming Meetings

AWWA SECTIONS

Oct. 14–17—Southwest Section, at Marion Hotel, Little Rock, Ark. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 15–16—Canadian Section, Maritime Branch, at Admiral Beatty Hotel, St. John, N.B. Secretary, J. D. Kline, Asst. Mgr. & Chief Engr., Public Service Commission, 62 Lady Hammond Rd., Halifax, N.S.

Oct. 18–20—New Jersey Section, at Hotel Madison, Atlantic City. Secretary, C. B. Tygert, Wallace & Tiernan Inc., Box 178, Newark 1.

Oct. 21–24—Alabama-Mississippi Section, at Battle House, Mobile, Ala. Secretary, Irving E. Anderson, Dist. Engr., Surface Water Branch, USGS, Box 2052, Jackson, Miss.

Oct. 23–26—California Section, at U. S. Grant Hotel, San Diego. Secretary, Henry J. Ongerth, Sr. San. Engr., Bureau of San. Eng., 905 Contra Costa Ave., Berkeley 7.

Oct. 24–26—Iowa Section, at Hotel Fort Des Moines, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

Oct. 24–26—Chesapeake Section, at Sheraton-Belvedere Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955 —33rd St., N.W., Washington 15, D.C.

Oct. 31–Nov. 2—West Virginia Section, at Hotel West Virginian, Bluefield. Secretary, Hugh W. Hetzer, Engr. Gen. Office, West Virginia Water Service Co., 179 Summers St., Charleston 1.

Nov. 7–9—Virginia Section, at Chamberlin Hotel, Old Point Comfort. Secretary, J. P. Kavanagh, Dist. Mgr., Wallace & Tiernan Inc., 213 Carlton Terrace Bldg., Roanoke.

Nov. 11–14—Florida Section, at Daytona Plaza Hotel, Daytona Beach. Secretary, Jay D. Roth, City Hall, Miami Beach 39.

Nov. 12–14—North Carolina Section, at Hotel Charlotte, Charlotte. Secretary, Wilbur E. Long Jr., 1615 Bickett Blvd., Raleigh.

(*Continued on page 10*)

Another city *using* AMERICAN'S *reinforced concrete pressure pipe for water supply lines*

The City of Phoenix, Arizona is another of the rapidly growing cities of the Southwest which have faced tremendous water supply problems and have met them successfully. The population of Greater Phoenix has increased almost 50 per cent in the past five years. An annexation program is currently increasing the rapid expansion of the City of Phoenix which is one of the fastest growing cities in the nation.

During 1953 American Pipe and Construction Company, through Fisher Contracting Company, general contractors, supplied Phoenix with more than 37,000 feet of large diameter concrete pressure pipe for a line which increased the Phoenix primary feeder capacity from 100,000,000 MGD to 210,000,000 MGD. The pipe furnished was pre-stressed concrete cylinder pipe designed for the operating pressures established under specifications prepared by Yost & Gardner, consulting engineers for the City of Phoenix.

American has helped to meet the special problems faced by Phoenix water officials by designing and supplying reinforced concrete pressure pipe especially for conditions in the Phoenix area.

A recent merger with Hooper Concrete Pipe Company in Phoenix gives American another permanent plant from which to serve the cities of the Southwest.

American Pipe and Construction Company makes available 49 years of experience and extensive production facilities to help solve any water supply problem. There is a type of American pipe to meet any requirement. Write or phone for complete information.

American PIPE AND CONSTRUCTION CO.

Concrete pipe for main water supply lines, storm and sanitary sewers, subaqueous lines

Mail address:
Box 3428 Terminal Annex, Los Angeles 54, Calif.

Main offices and plant:
4635 Firestone Blvd., South Gate, Calif., Phone LOrain 4-2511

District sales offices and plants:
Hayward and San Diego, Calif., Portland, Ore., Phoenix, Ariz.

Coming Meetings

(Continued from page 8)

Nov. 26–28—Rocky Mountain Section, at Broadmoor Hotel, Colorado Springs, Colo. Secretary, Jack W. Davis, Dist. Mgr., Transite Pipe Div., Johns Manville Sales, Inc., Denver, Colo.

Nov. 29–Dec. 1—Cuban Section, at Cuban Society Engineers Bldg., Havana. Secretary, Laurence H. Daniel, Pres., Laurence H. Daniel, Inc., Baratillo 9, Havana.

1957

Jan. 29—New York Section Midwinter Luncheon, at Park Sheraton Hotel, New York. Secretary, Kimball Blanchard, New York Branch Mgr., Rensselaer Valve Co., c/o Ludlow Valve Co., 11 W. 42nd St., New York.

Feb. 6–8—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, Robert J. Becker, Supt. of Purif., Indianapolis Water Co., 113 Monument Circle, Indianapolis 6.

Mar. 17–20—Southeastern Section, at Francis Marion Hotel, Charleston, S.C. Secretary, N. M. deJarnette, Engr., Div. of Water Pollution Control, State Dept. of Public Health, 245 State Office Bldg., Atlanta 3, Ga.

Mar. 20–22—Illinois Section, at LaSalle Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago 3.

Apr. 4–6—Arizona Section, at Maricopa Inn, Mesa. Secretary, H. C. Bigglestone, Luhrs Tower, Phoenix.

Apr. 5–6—Montana Section, at Rainbow Hotel, Great Falls. Secretary, Arthur W. Clarkson, Acting Chief, Water Sec., Div. of Environmental Sanitation, State Board of Health, Helena.

Apr. 10–12—Kansas Section, at Broadview Hotel, Wichita. Secretary, Harry W. Badley, Repr., Neptune Meter Co., 119 W. Cloud St., Salina.

Apr. 10–12—New York Section, at Mark Twain Hotel, Elmira. Secretary, Kimball Blanchard, New York Branch Mgr., Rensselaer Valve Co., c/o Ludlow Valve Co., 11 W. 42nd St., New York.

Apr. 24–26—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, John E. Olsson, 408 Sharp Bldg., Lincoln.

May 2–4—Pacific Northwest Section, at Winthrop Hotel, Tacoma, Wash. Secretary, Fred D. Jones, Asst. Supt., Water Dept., Rm. 306, City Hall, Spokane, Wash.

Jun. 12–14—Pennsylvania Section, at Bedford Springs Hotel, Bedford Springs. Secretary, L. S. Morgan, Div. Engr., State Dept. of Health, Greensburg.

Jun. 16–18—Canadian Section, at Royal Alexandra Hotel, Winnipeg, Man. Secretary, A. E. Berry, Director, San. Eng. Div., Ontario Dept. of Health, 72 Grenville St., Toronto, Ont.

OTHER ORGANIZATIONS

Nov. 12–16—American Public Health Assn., Atlantic City, N.J.

Nov. 27–30—National Chemical Exposition, sponsored by American Chemical Society, at Public Auditorium, Cleveland, Ohio.

YOUR BEST INVESTMENT FOR WATER LINES:

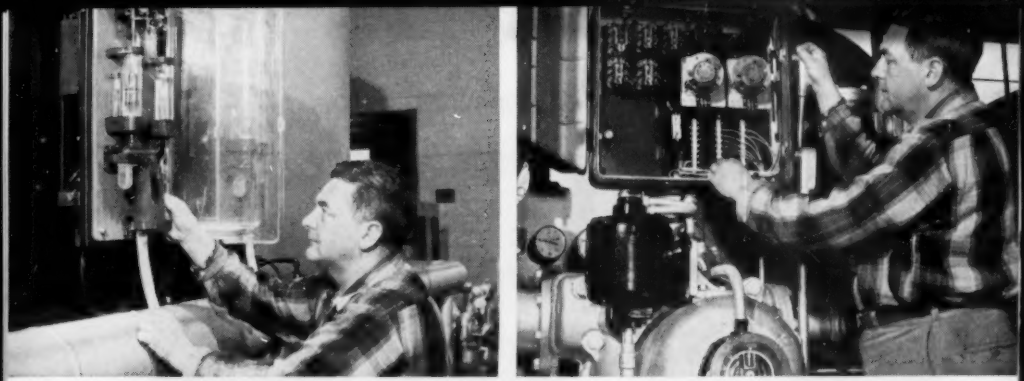
Steel Pipe . . . Protected by Bitumastic 70-B AWWA Enamel

Steel pipe lined and coated with coal-tar enamel is a combination that's hard to beat for long-life and economy in water service. The spun lining of Bitumastic® 70-B AWWA Enamel, approximately 3/32" thick, gives a waterproof coating that provides the longest life free of tuberculation, incrustation and corrosion. Steel pipe with a spun Bitumastic lining has the highest carrying capacity of any type of water pipe, and assures maximum delivery at minimum cost.

Take advantage of these economies—Specify steel pipe lined and coated with Bitumastic 70-B AWWA Enamel.

KOPPERS

BITUMASTIC
REG. U. S. PAT. OFF.
ENAMELS



HARDNESS TESTER (left) initiates regeneration by Automatic Controls (right). This new Permutit plant, with Q resin, softens 72% more water—using same manpower, less salt! E. Aurora, N. Y. Village Eng.: *E. J. Maurer.*

Why these cities chose PERMUTIT® *water conditioning*

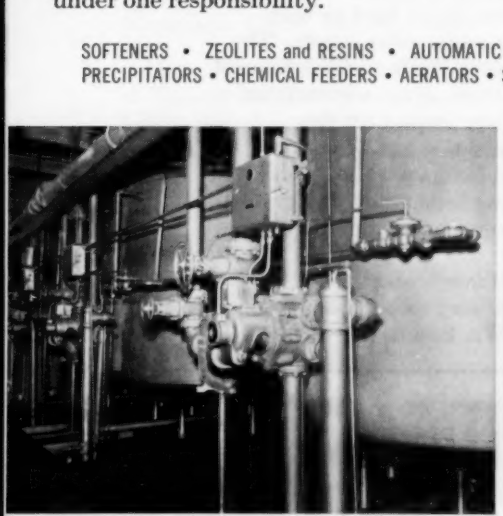
Some chose Permutit for its world-known engineering experience gained through thousands of installations covering every major development in clarification, filtration and softening equipment.

Others chose Permutit to get complete, integrated service: the water-analysis labs, engineering, equipment, controls, ion exchange resins—all from one source, under one responsibility.

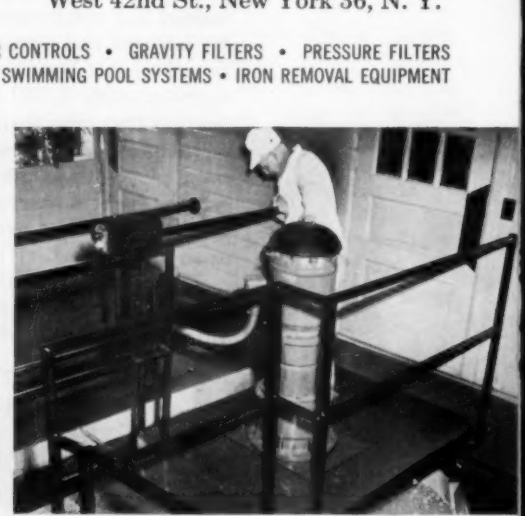
But most of the designers of these plants chose Permutit because they have personal knowledge of many installations where Permutit equipment has given long years of efficient, trouble-free performance. They know that's what pays off in the long run.

Write for Technical Bulletins. The Permutit Company, Dept. JA-10, 330 West 42nd St., New York 36, N. Y.

SOFTENERS • ZEOLITES and RESINS • AUTOMATIC CONTROLS • GRAVITY FILTERS • PRESSURE FILTERS
PRECIPITATORS • CHEMICAL FEEDERS • AERATORS • SWIMMING POOL SYSTEMS • IRON REMOVAL EQUIPMENT



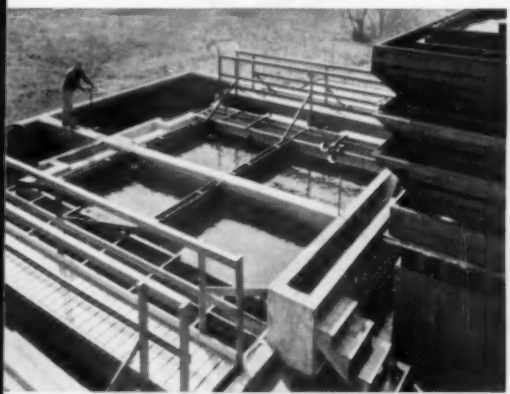
SOFTENER CAPACITY TRIPLED and $7,000 yearly saved on salt by change from zeolite to Permutit Q. Normal, Ill. Cons. Eng.: *Farnsworth & Conley.*



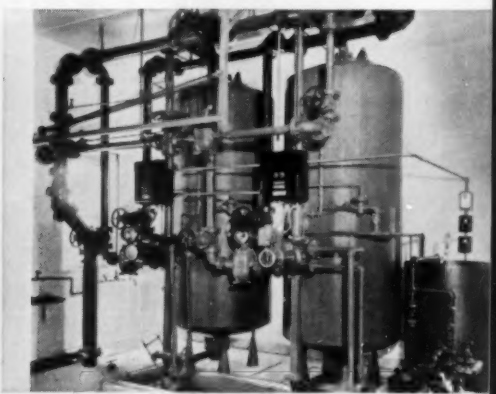
TRIPLE TROUBLE! 275 ppm hardness, 200 ppm alkalinity, 3 ppm iron are reduced by this Precipitator. Staples, Minnesota. Supt.: *E. H. Klang.*

TURBIDITY gets cut from 1500 to less than 5 ppm in this Precipitator. Mt. Carmel, Ill. Cons. Eng.: *Warren & Van Praag, Inc.*

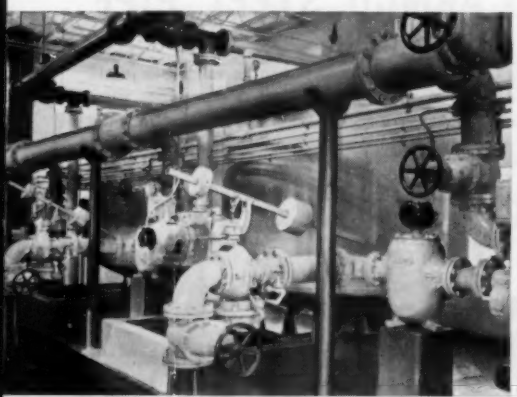
SEA WATER saves $32,980 per year over salt for regenerating Softeners. Hollywood, Fla. Cons. Eng.: *Reynolds, Smith & Hills.*



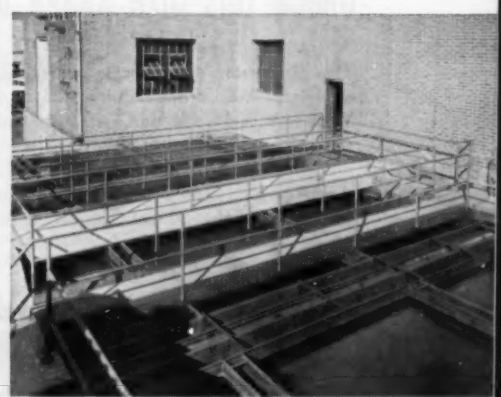
30 PPM IRON gets cut to 0.14 ppm in Aerator and Precipitator . . . even before filtration! Fairless Hills, Pa. Cons. Eng.: *H. H. Le Van, Jr.*



269 PPM HARDNESS is removed by these automatic Softeners. Aerator and Filters cut iron. Martinsville, Ill. Supt.: *O. Wiser.*



AUTOMATIC CONTROLS backwash, regenerate, rinse and return Softeners to service. New Smyrna Beach, Fla. Cons. Eng.: *Russell & Axon.*



OLD SETTLING BASINS house these modern Precipitators that boost capacity. North Kansas City, Mo. Cons. Eng.: *C. A. Haskins.*

ARMCO WELDED STEEL PIPE

Diameters and Wall Thicknesses

O.D. Inches	Wall Thickness Inches									
	.141	.172	.188	.219	.250	.281	.312	.375	.438	.500
6	■	■								
6⅝	■	■	■	■						
8	■	■								
8⅝	■	■	■	■	■					
10	■	■								
10¾	■	■	■	■	■	■				
12	■	■								
12¾	■	■	■	■	■	■	■			
14	■	■	■	■	■	■	■			
16	■	■	■	■	■	■	■	■		
18	■	■	■	■	■	■	■	■	■	
20	■	■	■	■	■	■	■	■	■	
22		■	■	■	■	■	■	■	■	■
24		■	■	■	■	■	■	■	■	■
26			■	■	■	■	■	■	■	■
28			■	■	■	■	■	■	■	■
30			■	■	■	■	■	■	■	■
32					■	■	■	■	■	■
34					■	■	■	■	■	■
36					■	■	■	■	■	■

Check this Size Range of ARMCO STEEL PIPE

This chart shows you the wide range of sizes of Armco Welded Steel Pipe—123 in all! With this wide selection, you can match water line requirements exactly.

More Advantages

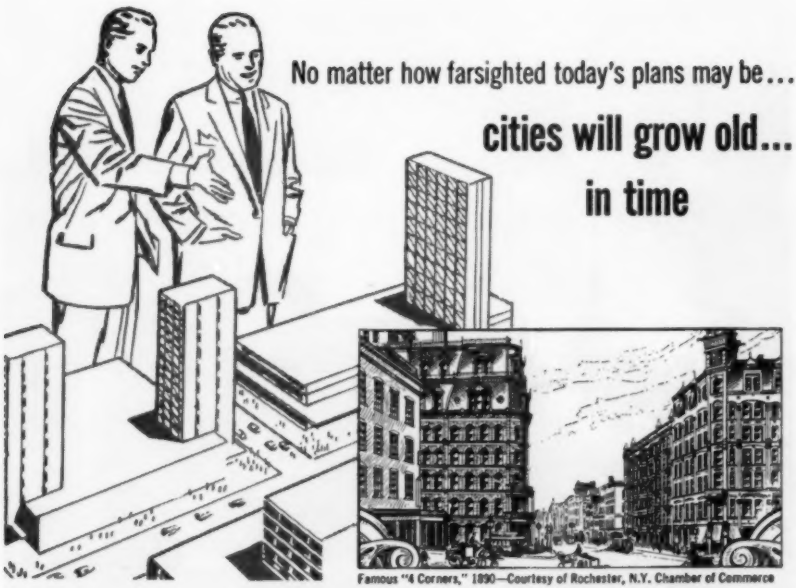
Armco Welded Steel Pipe is supplied in uniform lengths up to 50 feet. This means there are fewer sections to handle and fewer joints to make. Work goes fast. Write us for more data. Armco Drainage & Metal Products, Inc., Welded Pipe Sales Division, 4546 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada write: Guelph, Ontario.

ARMCO Welded Steel Pipe

Meets A.W.W.A. Specifications

ARMCO®

WHEREVER WATER FLOWS, STEEL PIPES IT BEST



No matter how farsighted today's plans may be...

cities will grow old... in time

Famous "4 Corners," 1890—Courtesy of Rochester, N.Y. Chamber of Commerce

Your best insurance against obsolescence of your water system... specify EDDY Valves and Hydrants *throughout*

No matter how far into the future your city planning is projected, Eddy's record testifies that Eddy Valves and Hydrants are your best long term investment. Eddy Valve Company's more than 100 years of dependable operation means that, today, you can get replacement parts for any Eddy Valve or Hydrant ever installed. And our ability to continue to do so is your assurance against future obsolescence of your valves and hydrants.

EDDY Bronze-Mounted HYDRANTS open smoothly *with* the pressure and close without water hammer. One man can easily remove all operating mechanism for inspection and repair. Stem held in place below hydrant valve means that there is no water loss due to a bent stem.

EDDY Bronze-Mounted GATE VALVES offer simplicity of design, trouble-free operation and enduring service. Each is truly a finished product of workmanship. These factors, added to personal experience, tell why progressive water works men have relied on Eddy for generations.

Eddy Hydrants and Valves are available with hub, flange or mechanical joint connections to fit any existing or planned installation.

EDDY VALVE COMPANY
WATERFORD, NEW YORK

'Red Water' doesn't live here any more!

No more 'Red Water'—thanks to Threshold Treatment with Calgon*—that's the record in this typical community.

When Calgon treatment was started, 'Red Water' stopped, and now everyone is complimenting the water superintendent.

Calgon in very small amounts is effective against 'Red Water' because it not only stabilizes iron and manganese dissolved in water at its source, but it also prevents iron pickup from pipes.

Calgon stops lime scale, too, by forcing calcium carbonate and other scale-forming chemicals to stay in solution, even when the water is heated. Calgon is used in minute amounts, and the reduction of lime scale means important savings in keeping equipment and meters clean.

Call on Calgon for the economical solution to your specific problem. Many years of experience with water problems of all kinds in every part of the country are at your service.

*Calgon is the Registered Trade Mark of Calgon, Inc. for its glassy phosphate (sodium hexametaphosphate) products.

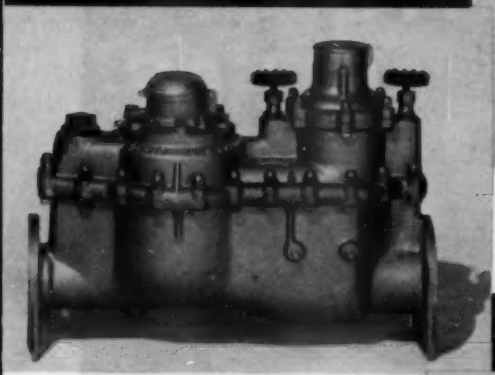
HAGAN

calgon, inc.

A Subsidiary of Hagan Corporation
Hagan Building • Pittsburgh 30, Pa.

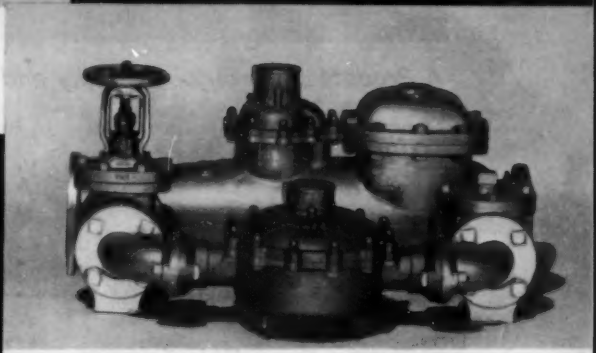
HERSEY DISC WATER METERS

for domestic services



HERSEY
COMPOUND WATER METER

All bronze case 2" to 6" inclusive



HERSEY DETECTOR (Fire Service) **METER**
with DISC METER on BY-PASS

Also furnished with All Bronze Case Compound Meter on By-Pass for special types of service

For all types of efficient Water Meter Service

HERSEY WATER METERS

have never been surpassed for accurate registration and low maintenance costs.

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS — CHICAGO
SAN FRANCISCO — LOS ANGELES

A Product of Unvarying Quality and Uniformity

General Chemical Aluminum Sulfate is the standout coagulant for removing turbidity from water, and for reducing colors, tastes and odors. It is an easy-to-use, effective means of giving people far better water at lowest possible cost.

Your Most Dependable Supplier!
Even in emergencies such as flood catastrophes, you can be sure of supplies of General Chemical Aluminum Sulfate. There are twenty-five producing works strategically located across the country to provide prompt service anywhere, anytime!

For Water Treatment

- Produces crystal clear water
- Gives better floc formation
- Promotes better settling and longer filter runs
- Has no chlorine demand
- Aids in reduction of tastes and odors
- Is a low cost coagulant
- Superior in tests against other coagulants
- High in quality. Its constant uniformity can be depended upon

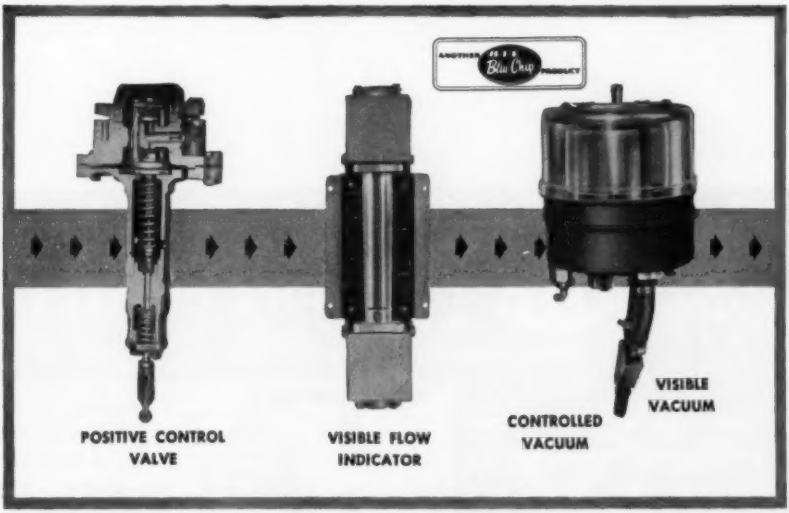
For Sewage Treatment

- Clean, easy to handle
- Dry feeds well or dissolves readily for solution feeding; liquid alum also available in many areas
- Simple application. Requires only low-cost feeding apparatus and minimum attention
- Clear, colorless effluents are possible
- Sludge digests readily
- Treated digested sludge dries quickly with minimum of odor
- Chlorine consumption is cut, due to lower demand of clarified sewage
- Economical to use

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport • Buffalo Charlotte • Chicago • Cleveland • Denver • Detroit • Greenville (Miss.) • Houston Jacksonville • Kalamazoo • Los Angeles • Milwaukee • Minneapolis • New York Philadelphia • Pittsburgh • Providence • San Francisco • Seattle • St. Louis • Yakima (Wash.)
In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver

Basic Chemicals for American Industry



IN CHLORINE GAS FEEDERS . . .

LOOK FOR KNOW-HOW

Here's proof of good chlorine feeder design! The gas flow path shown in this Builders-Providence flowgram is the shortest offered by any manufacturer of chlorination equipment . . . and we invite comparison! Good design means maximum dependability (to the consulting engineer) . . . ease of installation (to the contractor) . . . and easy operation, low upkeep, and low operating cost (to the operator).

Our design offers all these and more. For added safety . . . there are no springs or piloted parts in contact with chlorine, no packed valve stems to leak and destroy feeding accuracy . . . and the simplicity of the entire system means better operation with less maintenance.

These superior features did not just happen — but are drawn from the vast reservoir of B-I-F application knowledge and experience gained as the major manufacturer of flow metering, and control equipment for WATER, SEWAGE, and WASTE TREATMENT PLANTS. Many consulting engineers have profited by the valuable assistance received from B-I-F specialists. Our policy of continuing research and development has produced the most comprehensive, service-proven line available . . . and thousands of superior performance records reflect our broad design and manufacturing experience.

* * *

If you have a chlorine gas feeding problem, our engineers will gladly help you solve it. A call to GAspee 1-4302 in Providence . . . or to one of our local offices . . . will put us at your service. B-I-F Sales and Service Offices are located across the country for your convenience. Act today! Builders-Providence, Inc., 285 Harris Avenue, Providence 1, Rhode Island.

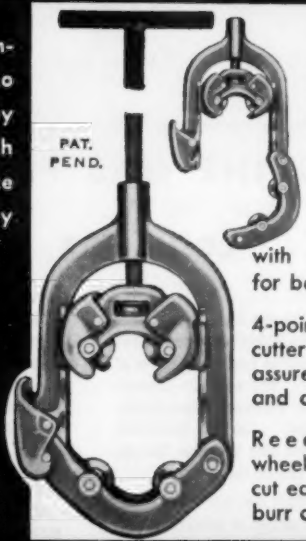
B-I-F INDUSTRIES

PROVIDENCE, RHODE ISLAND

B-I-F METERS FEEDERS CONTROLS

IF YOU CUT LARGE DIAMETER PIPE...
YOU NEED THESE
New REED HINGED 4-WHEEL PIPE CUTTERS
Four sizes cover the range from 2½" to 12"

Users tell us these completely new cutters are so efficient they often "pay for themselves" through the savings in crew time on a half-dozen cuts. They are the first really practical tools for cutting off steel or cast iron pipe in sizes from 2½" to 12". You can, for example, cut 8" steel pipe completely off in less than five minutes.



Four wheel design requires minimum swing of handle—less digging in ditch work, easier "tight-corner" cuts.

Closed frame permits light weight with complete rigidity for better cutting.

4-point guide aligns the cutter on the pipe . . . assures perfect tracking and a right angle cut.

Reed Razor Blade wheels track perfectly, cut easily and roll down burr on steel pipe.

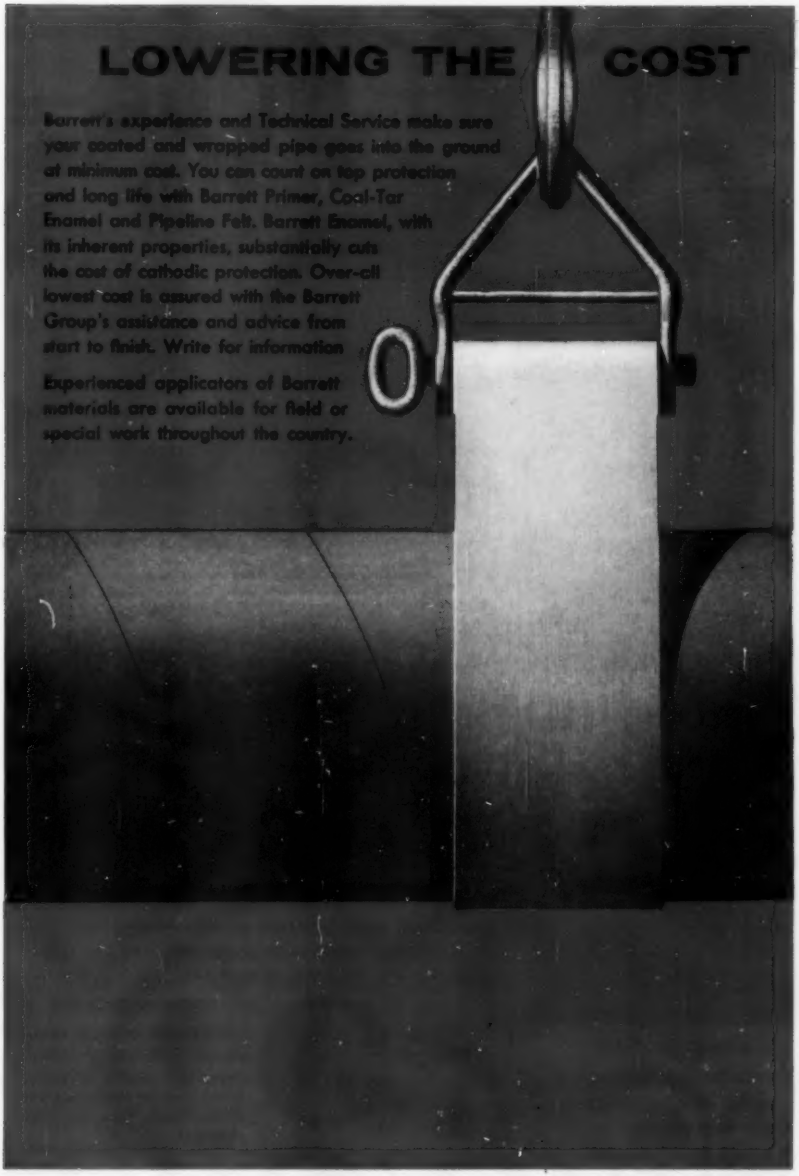
Unconditionally guaranteed to be the most efficient cutter you have ever used. Ask your jobber or write for literature.

REED MANUFACTURING COMPANY
ERIE, PENNSYLVANIA • U. S. A.

LOWERING THE COST

Barrett's experience and Technical Service make sure your coated and wrapped pipe goes into the ground at minimum cost. You can count on top protection and long life with Barrett Primer, Coal-Tar Enamel and Pipeline Felt. Barrett Enamel, with its inherent properties, substantially cuts the cost of cathodic protection. Over-all lowest cost is assured with the Barrett Group's assistance and advice from start to finish. Write for information

Experienced applicators of Barrett materials are available for field or special work throughout the country.



Barrett®

PROTECTIVE COATINGS

BARRETT DIVISION, Allied Chemical & Dye Corporation, 40 Rector Street, New York 6, N. Y. In Canada: The Barrett Company, Ltd., 5551 St. Hubert Street, Montreal, Que.

Allied Chemical

OVER 100 YEARS OF EXPERIENCE

The Superior
COAGULANT
With the Plus
FACTORS—

1. Excellent Taste and Odor Control
2. Coagulation Over Wide pH Range
3. Rapid Floc Formation
4. Color Removal
5. Bacteria Removal
6. Turbidity Removal
7. Manganese and Silical Removal
8. Ease of Operation
9. Economical
10. Increased Filter Runs

Ferri-Floc gives smoother, more efficient and trouble free coaguiation. Whatever your particular water treatment problem may be, you can depend on Ferri-Floc doing a more than adequate job and doing it efficiently and economically—Ferri-Floc is a free flowing granular salt which can be fed with few modifications through any standard dry feed equipment. It is only mildly hygroscopic, thereby permitting easy and safe handling as well as storage in closed hoppers over long periods of time.

WATER TREATMENT

Efficient coagulation of surface or well waters. Aids taste and odor control—Effective in lime soda-ash softening. Adaptable to treatment of nearly all industrial waters.

SEWAGE TREATMENT

Ferri-Floc coagulates water and wastes over wide Ph ranges—it provides efficient operation regardless of rapid variations of raw sewage and is effective conditioning sludge prior to vacuum filtration or drying on sand beds.

SULFUR DIOXIDE

SULFUR DIOXIDE is effectively used for dechlorination in water treatment and to remove objectionable odors remaining after purification.

LIQUID SULFUR DIOXIDE HIGHEST QUALITY SO_2

COPPER TC SULPHATE

COPPER SULFATE

COPPER SULFATE will control about 90% of the microorganisms normally encountered in water treatment more economically than any other chemical.

Let us send you without charge, a 38 page booklet that deals specifically with all phases of coagulation—just send us a postal card.

TENNESSEE TC CORPORATION

617-29 Grant Building, Atlanta, Georgia

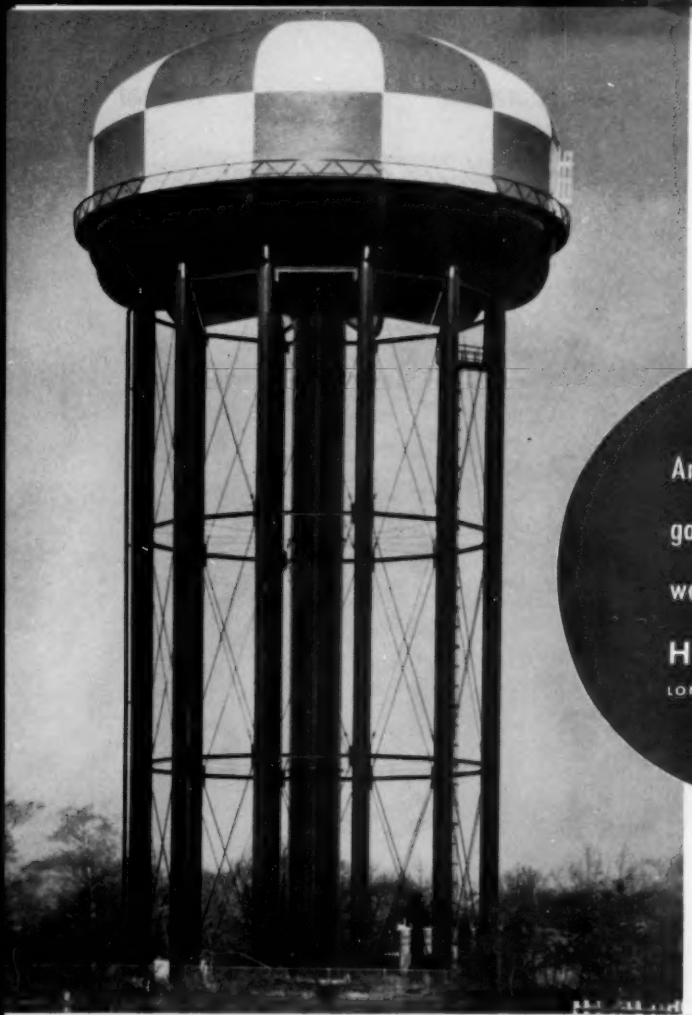
INSTALL with a **RATCHET WRENCH**

Any type and size of M & H Valve or Hydrant can be furnished with standardized Mechanical Joint end connections, to fit mechanical joint pipe and fittings made by different manufacturers.

The use of Mechanical Joints has spread steadily for 40 years until today it is more widely used than any other type of joint because it offers many advantages. M & H Mechanical Joint Valves and Hydrants are used not only with mechanical joint pipe but are easily installed in old bell-and-spigot pipe lines.

The joint is made by a bolted gland compressing a thick gasket into a stuffing box. The joint assembly is simple, rapid and practically foolproof. The gasket used for water mains is composition rubber, but metal-tipped, duck-tipped, Thiokol-tipped and other special gaskets can be supplied. The joint is bottle tight, and permits deflection, expansion or contraction without leakage. Write or wire

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA



Another 1,500,000
gallons of "certain-sure"
water service for
HEMPSTEAD
LONG ISLAND, N. Y.

1951

Elevated Steel Tanks by

PITTSBURGH-DES MOINES

Latest of the many PDM Elevated Steel Tanks towering over Long Island's level terrain is this 1,500,000-gallon Radial Cone installation for Hempstead. 88 ft in diameter, the tank has a headrange of 35 ft and is on a tower 135 ft to bottom of capacity. Shown at right is an earlier million-gallon PDM tank of the same design, built for Hempstead in 1951.

● Write for our new Modern Water Storage Catalog.

PITTSBURGH • DES MOINES STEEL CO.

Plants at PITTSBURGH, DES MOINES, SANTA CLARA, FRESNO, and CADIZ, SPAIN

Sales Offices at:

PITTSBURGH (25). . . . . 3424 Neville Island	DES MOINES (8). . . . . 925 Tuttle Street
NEWARK (2) . . . 221 Industrial Office Bldg.	DALLAS (1) . . . . 1229 Praetorian Building
CHICAGO (3) 1228 First National Bank Bldg.	SEATTLE . . . . . 532 Lane Street
EL MONTE, CAL. . . . . P. O. Box 2068	SANTA CLARA, CAL. . . 631 Alviso Road
MADRID, SPAIN . . . Diego DeLeon, 60	

PDM
ELEVATED STEEL TANKS

The "Baffling" answer to your flocculation problems

Here's the answer to more efficient, economical flocculation—the Rex Floctrol. Designed with a unique combination of mixing paddles, rotating baffles and fixed partition walls, this exclusive Rex® development gives you these outstanding advantages:

- Minimum amount of chemical required...low cost.
- Flexibility...tank sizes, paddle and baffle arrangements to suit any condition or volume.
- Large, readily settleable floc.
- No "short circuiting"...paddle axis parallel to line of flow.
- Low horsepower cost... no wasted power "bucking" flow.

The cross section below indicates the efficiency of the Floctrol design...small rotating influent baffles and large effluent baffles assure full utilization of tank volume. These proportioned baffles and ports eliminate short circuiting...reduce amount of chemicals needed...assure most efficient flocculation.

For complete information, write CHAIN Belt Company, 4609 W. Greenfield Ave., Milwaukee 1, Wis.

CHAIN BELT COMPANY
Milwaukee 1, Wisconsin

"Planting" Lancaster's New Water Line

Lancaster, Pa., has a vast water-supply project under way. It includes construction of an intake, pumping station, filtration plant, a 15-million-gal reservoir and a 10-mile tar-enameled steel main. Completion of the system early in 1957 will add 8 million gals per day to the city's water supply.

Frank Kukurin & Sons, Inc., of E. McKeesport, Pa., and Alconn Utilities, Inc., of Verona, N. J., were awarded the two pipe-laying contracts. Engineering is by Gannett, Fleming Corddry & Carpenter, Inc., of Harrisburg, for the City of Lancaster Authority. Bethlehem is supplying 55,500 ft of 42-in.-ID x 5/16-in. tar-enameled steel pipe in 40-ft lengths.

Are you planning a new water main? The people at your nearest Bethlehem sales office would be happy to discuss it with you.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation.

Export Distributor: Bethlehem Steel Export Corporation

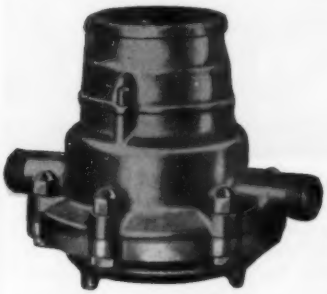
BETHLEHEM STEEL

BETHLEHEM STEEL

The Safest Meter to Buy is AMERICAN

Because We Have Freezing Weather

"American Frost Bottom Meters have complete frost protection—frost-separable gear train and chamber, with pre-tested breakable bottom. That reduces parts replacement costs, to the absolute minimum. I repair 'em. I know American is the safest meter to buy."



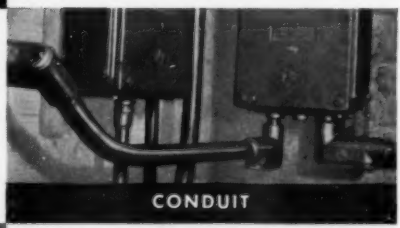
• In American Meters you know in advance what will happen in freezing. The frost bottom breaks, relieving pressure, so that internal working parts are not damaged. The bottom can be replaced in a few minutes. No complicated repair jobs. No expensive working parts to replace. No extra load on the repair department. That's why Repairmen say, "American is the safest to buy!"

BUFFALO METER CO. 2914 MAIN STREET BUFFALO 14, N. Y.

Proved Protection against Corrosion with EVERDUR

Everdur is Readily Fabricated. Everdur alloys are available for hot or cold working, welding, free-machining, forging and casting—and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

Everdur* Resists Corrosion. Installations of Everdur sewage treatment and waterworks equipment in the United States have been in service without replacement for 20 years and longer—evidence of Everdur's ability to resist corrosion common to these operations. *Reg. U. S. Pat. Off.



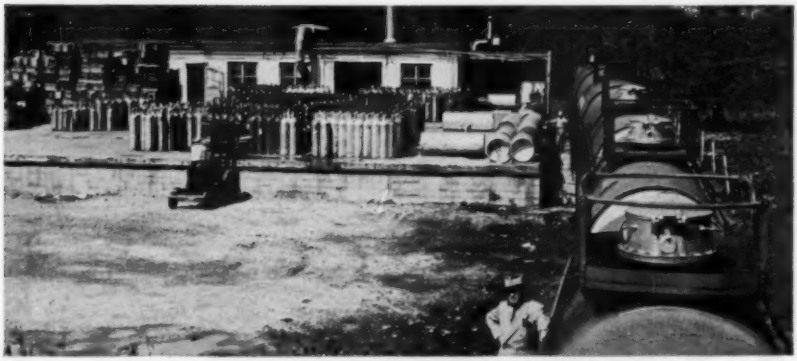
Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage and Waterworks Equipment"—or for assistance of the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 56130

Everdur is Tough. Everdur, Anaconda's group of copper-silicon alloys, also possesses high physical strength and resistance to wear and abrasion—so that wrought equipment can be designed with lighter weight.

ANACONDA®

COPPER-SILICON ALLOYS

STRONG • WELDABLE
WORKABLE
CORROSION-RESISTANT



AT SIX PLANTS ACROSS COUNTRY, the Jones Company receives tank cars of Chlorine, repackages it in cylinders and ton-tanks, makes quick deliveries to users in area.

CHLORINE

Fast delivery on less-than-carload lots

Pick Your Own Chlorine Product and Container

LIQUID CHLORINE In 16-, 105-, 150-lb. cylinders and 1-ton tanks.

CALCIUM HYPOCHLORITE (70% available Chlorine) 3¾- and 5-lb. tins, 100-lb. drums.

SODIUM HYPOCHLORITE Gallons, carboys. Tankwagon deliveries in 1000-3000 gal. lots.

You get swift delivery—and NO storage worries—when you turn your Chlorine problem over to John Wiley Jones Company. Six plants, strategically located across the U.S. stand ready to supply you.

Order shipments as small as a 16-lb. cylinder of liquid Chlorine, and as large as you want. With this flexibility, you eliminate storage problems. We supply more municipalities than all other Chlorine packers combined.

Quality is exceptional—meets high government standards!

Our trained technical staff will be glad to help you solve your Chlorine problem. Write for prices.

JOHN WILEY JONES CO.

100 Sunny Sol Blvd.
Caledonia, New York
Tele—Caledonia 84, 79, 4

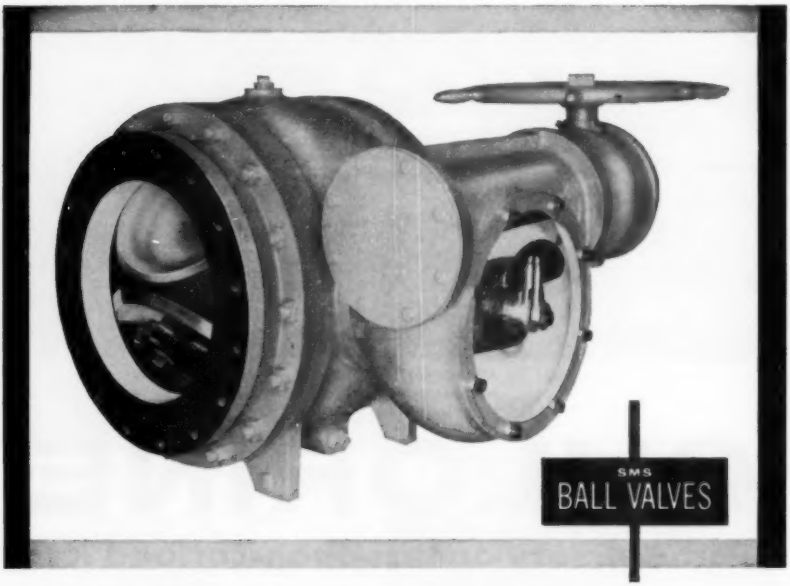
1904 Border Ave.
Torrance, Calif.
Tele—Fairfax 8-6383

600 Bethel Ave.
Beech Grove
(Indianapolis), Ind.
Tele—
Idlewood 1443, 1444

2365 Dennis St.
Jacksonville, Fla.
Tele—Elgin 4-5503
6-3321

610 McNinch St.
Charlotte, N. C.
Tele—6-7790

14400 N.E. 20th Lane
North Miami, Fla.
Tele—North Dade 6-6288
or Dial 81-6-6288



FLOW ITSELF HELPS MAKE

SMS BALL VALVES EASY TO CLOSE

Flow velocity actually assists the closing operation of SMS Ball Valves. With the hydraulic action boosted by the powerful leverage of the simple link and lever mechanism (visible through the lucite cover of the demonstration model above), the valve is remarkably easy to close. The wedging action of the metal-to-metal seats assures drop-tight closure.

In the open position, the valve is like a straight length of pipe. Pressure drop and turbulence are kept to a minimum, resulting in lower pumping costs and longer valve life.

The high quality and peformance characteristics of SMS valves are guaranteed by over 75 years of research and engineering. For detailed information about our complete line of Ball Valves, Rotovalves and Butterfly Valves, see your local representative, or write to the S. Morgan Smith Company, York, Pennsylvania.

HYDRAULIC TURBINES
PUMPS
GATES & HOISTS
TRASH RAKES
ACCESSORIES
HYDRODYNAMICS
ROTOVALVES
BALL VALVES
BUTTERFLY VALVES
FREE-DISCHARGE VALVES
CONTROLLABLE-PITCH SHIP PROPELLERS

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED • TORONTO

YOU WERE DOING THIS

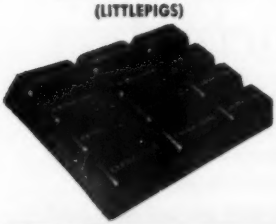
WHEN THE FIRST HYDRO-TITE JOINTS WERE BEING POURED -

HYDRO-TITE (POWDER)

HYDRO-TITE (POWDER)

For over 40 years HYDRO-TITE has been faithfully serving water works men everywhere. Self-caulking, self-sealing, easy-to-use. Costs about 1/5 as much as lead joints. Packed in 100 lb. moisture-proof bags.

HYDRO-TITE (LITTLEPIGS)



HYDRO-TITE (LITTLEPIGS)

The same dependable compound in solid form —packed in 50 lb. cartons—2 litters of pigs to the box—24 easy-to-handle Littlepigs. Easier to ship, handle and store.

FIBREX (REELS)

FIBREX (REELS)

The sanitary, bacteria-free joint packing. Easier to use than jute and costs about half as much. Insures sterile mains and tight joints.

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

[illegible] Church Street, New York [illegible] W. Medford Station, Boston, Mass.

WALLACE & TIERNAN
V-NOTCH
variable-orifice
CHLORINATORS
A-711 V-notch Chlorinator has rotameter indicator with 10 to 1 feed range
A-712 V-notch Chlorinator has dial indicator with 20 to 1 feed range

NEW *V-notch Chlorinators*
SIMPLIFY *Chlorination*

With the new Wallace & Tiernan V-notch Variable-Orifice Chlorinators:

OPERATION IS SIMPLIFIED as one injector control starts or stops the unit. Chlorine gas is turned on or off automatically.

SETTING FEED RATE IS SIMPLIFIED as one control sets feed rate precisely at both high or low feeds.

INSTALLATION IS SIMPLIFIED as units are shipped ready for operation. No water supply is needed at the chlorinator. A remote injector uses only standard water supply fittings.

MAINTENANCE IS SIMPLIFIED and virtually eliminated. All parts are corrosion resistant, mounted in an attractive modern cabinet.

For full details on manual or automatic proportional V-notch Chlorinators, contact your W&T representative, or write to the address below.

A New Development from Wallace & Tiernan Research

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

S-112

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 48 • OCTOBER 1956 • NO. 10

Management Reorganization of Philadelphia Water Department

Samuel S. Baxter

A paper presented on May 9, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Samuel S. Baxter, Water Comr., Philadelphia, Pa.

THE idea that water service to a community is a public utility and should be operated as such is not new. Many public departments, boards, and private companies are operating on this basis. It is of interest, however, when the third largest city in the country changes over from the old style of governmental operation to the concept of utility operation, and at the same time keeps that operation within the overall organization of the municipal government.

History

The Philadelphia Water Department has, in one form or another, been in continuous operation as part of the city government since 1799, when it was formed to bring water into the city. At that time, the city had an area of 2 sq miles. In 1854 the city area was expanded to 130 sq miles, with the Philadelphia Water Department taking over some small water units in the annexed territory. Much of this expanded territory was rural, and its development as urban areas has occurred over the last 100 years, with the area remaining the same.

Through practically all of its development and growth, water service was furnished and operated on what can be termed the governmental basis. It was operated as a bureau or a department in the regular organizational structure of the city government. Its expenditures were paid from the general fund of the city in the same way that other governmental expenditures were made, and revenues from water sales were deposited in the general fund as part of overall income. Needless to say, this plan was not considered ideal for a water service operated as a utility.

In addition, the services of the department itself suffered because it was classified as another governmental

agency rather than as a utility with high standards of service. To the credit of many men in the past, these standards often rose above the general level of the standards of city government, but the inherent drawbacks in the system did not permit water service to be established on the same standards as such other utilities as gas, electricity, and telephone.

Beginning in 1888 the Bureau of Water was formed in the Department of Public Works, and this bureau continued until 1952. Many commendable projects were undertaken during part of this period, outstanding of which was the construction of slow sand filter plants for the entire city in 1900–10. Problems began to develop in the 1920's and they became more acute in the 1930's and 1940's. Industrial pollution in the rivers supplying raw water to Philadelphia brought serious problems of treatment and taste and odor control; as a result of these difficulties, Philadelphia water gained a reputation for poor quality which was known nationwide. Older parts of the plant—not only treatment plants but pumping stations and distribution systems—began to deteriorate without money for replacement. Although in many of the years income from water sales exceeded costs, all of the money went into the general fund and much was diverted which should have been used in modernizing plant and equipment and in establishing high standards of service.

New Charter

Many of these shortcomings were evident to people in the professional and business world in Philadelphia, and to those in city government who knew the problems involved. Many solutions were offered and discussed, and one which aroused considerable interest was that the entire water works should be transferred to a public authority which would operate the service as a public utility, entirely separate from the remainder of the Philadelphia city government. Late in the 1940's a movement was also started for the enactment of a new city charter which would give Philadelphia almost complete home rule in the formation and operation of its city government. One of the foremost problems was what to do with the operation of the water system and its sister service, the sewer and sewage treatment system. The latter had had a much smoother past than the water system had.

In framing the charter, proponents of the authority method were faced with objections to turning over the water service to an independent agency, particularly as no other governmental agency was involved except the city of Philadelphia. The net result of all the deliberations was the enactment of a charter calling for the creation of a water department within the regular framework of the city government but giving it certain duties and powers to enable it to operate as a self-sustaining utility.

The charter provisions are rather brief. They give the Water Department the power and duty to operate the city's water supply system and sewage system and sewage disposal plants and to construct new facilities; to fix and regulate rates for water and sewage services, subject only to standards which the City Council might fix, and to compute these rates so as to yield an amount equal to all operating expenses, interest, and sinking-fund charges; and to include in operating expenses all services performed for

the Water Department by other departments.

The charter also contains a provision concerning service to areas outside the city limits, and the proponents of the authority method of operation were able to include a clause permitting that type of operation at any time in the future, if the council so ordains.

The experience under this new charter, which went into effect in January 1952, must be viewed in the light of a general renaissance in the city government which came along with the charter. Although the change was made notable by the fact that the political party which had been in power for a long time was removed from office, the most outstanding factor was apparently the demand of people in both parties for some reforms in the municipal government. The new charter became a symbol of this demand for a modern government, and its enactment by vote of the people was evidence of this.

The new water department, with its entirely different concept of operation, came into being in this aura of the demand for new, efficient, and modern governmental facilities. This atmosphere had much to do with getting the new department off to a good start and in establishing the basic principles which were needed to implement the charter.

The new charter called for a strong-mayor type of government. It included many of those things which have been associated with this form of government, including the abandonment of the old line-by-line type of budget for lump sum appropriations, and the establishment of strong finance and personnel departments. It set up a managing director who was to be responsible for the operation of ten service departments and responsible to the mayor. The water department is one of these service departments.

Department Organization

The new department was organized into four basic units. These reported to the commissioner who is designated by the charter as being responsible for the operation of the department.

The Water Operations Division is responsible for the operation of all of the water facilities in the department, with major subdivisions covering treatment, pumping, distribution, metering, customer service, and automotive maintenance. The Water Operations Division is under a deputy commissioner.

The Sewage Operations Division is responsible for the entire operation of the sewer system and the sewage treatment plants, with major subdivisions for sewage treatment, sewer maintenance, and industrial wastes. The Sewage Operations Division is under a deputy commissioner.

The Engineering Bureau is responsible for the design and construction of all new facilities, both for sewer and water services. This bureau is under a chief engineer.

The Administrative Division is responsible for such general administrative work as personnel, accounting, rates, and budget. This unit is under the direction of an administrative services officer.

In the preliminary planning, considerable thought was given to the type of organization in which there would be two separate divisions, one to operate all water service, including the construction of new work in one division, and another to operate sewer and sewage treatment services, including construction of new work. Because of

the large amount of new construction work then underway and in the planning stage, it was decided to create a separate engineering bureau for the design and construction of new facilities, thus divorcing the operating divisions from such projects, except for consultation and advice on operating matters.

The new organization is not intended to set up an entirely complete and separate organization to handle water and sewer services. The Water Department, for instance, does not read meters or prepare and send out water and sewer bills, as will be discussed later. Nor does the department have complete authority over finance, accounting, personnel, and procurement. These functions must operate within the general framework of the city government, as set up in the charter, and they are subject to procedures and regulations which are promulgated by the department in charge. This will also be discussed later.

Although the sewerage and sewage treatment division has also had an interesting development, with a sewer rental to support its operation and with new treatment plants finished in the last 5 years to treat all city sewage, the remainder of this discussion will be concerned with the development of the water service.

Finance

One outstanding step in the entire reorganization was the creation of a separate water fund and a separate sewer fund, both entirely distinct from the general fund of the city. As a result of the authority given by the charter, these funds have been established together with separate budgets for enactment by the city council. All costs of the operation of the Water Department must come from moneys in the water and sewer funds, and all revenues from water and sewer rents and from other charges related to water and sewer services are deposited in these funds. For what is probably the first time in the history of Philadelphia, customers can be told that they are paying their "water rent" only for water service, and that the service which they are getting is related directly to the amount they pay.

Income includes not only regular charges for water service, but also a charge payable from the general fund to the water fund for water furnished to city buildings, and a charge per hydrant for fire-fighting costs. It also includes an amount payable from the general fund to the water fund for the direct cost of the high-pressure fire-fighting system which is operated by the water department. Conversely, the water fund pays into the general fund amounts which include the cost of meter-reading and billing service operated by the Department of Collections, the repaving work which is done for the Water Department by the Streets Department, communication service which is furnished by another city department, and a proportionate cost of the operation of the other departments furnishing services or having general supervision over the Water Department, including finance, personnel, law, managing director, mayor's office, city council, and payment for rental of space occupied by the main offices of the department in the general city office building.

Rates

A unique feature of the operation of the Water Department under the new charter is that relating to rates. As far as can be determined, the provi-

sions of the charter on this subject do not exist in any other reasonably large city in this country. The charter says: "In accordance with such standards as the Council may from time to time ordain, the Water Department shall fix and regulate rates and charges for supplying water, including charges to be made in connection with water meters, and for supplying sewage disposal services."

The interpretation of this clause and the responsibility of the various parties concerned were the first problems faced by the new department. This was particularly true when it became evident during 1952 that the existing water rates would have to be increased in order to meet the self-sustaining features of the charter.

The charter apparently gave the Water Department the power to fix rates, subject only to such standards as the council would ordain. The annotated notes which accompanied the charter, although they have no legal weight themselves, gave some evidence of what the framers had in mind. These notes said that the Water Department was to fix rates so that this function would not be subject to the political pressures that have been brought to bear upon the council when it has undertaken to perform this task. The notes went on to say that ratemaking for utility service has been regarded as an administrative function, subject to legislative standards, and that the council is to ordain the standards.

During 1952, the council itself adopted no special ordinance-fixing standards. This portion of the charter had not been too widely discussed during its enactment period, and the councilmen were somewhat startled to find that this prerogative, which at least in Philadelphia had long been considered as a legislative one, had now been placed in the hands of a single administrative officer.

Faced with the demand for new 1953 rates, however, the department went ahead and, in 1952, prepared and promulgated rates to become effective on Jan. 1, 1953. As a matter of interest, these rates increased the minimum charges by 31 per cent, and the charges for additional water by 55 per cent.

The new rates, although still among the lowest in the country, included increases which were caused by the inclusion of many items of cost which formerly had been spread among the budgets of other departments. The new rates were designed also to meet the debt charges necessitated by new construction, as will be discussed later.

In preparing the rates during 1952, the general standards and methods used in Pennsylvania for private water utilities were adopted. Many variations had to be made for Philadelphia, but, in the absence of any regulatory or reviewing authority, it was deemed advisable to follow basic principles established by the Pennsylvania Public Utility Commission for private water companies and other principles which had been laid down by court decisions for private and public water utilities.

This precaution turned out to be a good one. Shortly after the adoption of the new rates, a group of extensive water users filed a petition with the court, attacking the fairness of the rates. Because of various circumstances, the trial was not held until late in 1954. At that time, the plaintiffs not only claimed that the rates in themselves were unfair and discriminatory, but they also attacked the entire constitutionality of that portion of the charter which gave the water department

authority for ratemaking. In the case of *Monaghan* v. the *City of Philadelphia* (*1*), the lower court handed down its decision in June 1955: the court not only upheld the fairness of the rates but also sustained the constitutionality of the charter provisions concerning ratemaking powers. Among other things, the court held that, in adopting the overall budget for the water department, the council had fixed a standard of operation, and the department could fix rates within that limit. Although the plaintiffs filed exceptions to the decision, they did not press for an argument or hearing on the exceptions, and the decision still stands.

The court upheld other interesting phases of the rate structure, such as special rates for charity organizations and the ability of the city to pay off some of its capital costs on a pay-as-you-go basis.

Accounting

One of the earliest problems faced by the new department was the absence of a modern water works accounting method. The decision was made to install a modern cost-accounting system based on the Association's manual (*2*). The job of installing such a system for an operation as large as that at Philadelphia was a fairly complex one, and the procedure was somewhat complicated by the fact that the charter placed the responsibility for all accounting on the Finance Department. As a result, the entire system was not completed and ready for operation until the start of the calendar year 1955. The value of this system as a tool for management in checking operations and costs may be evident to those who use it, but its absence was very evident in the work of organizing the Philadelphia water department on a sound utility basis. It was also helpful for ratemaking problems, and the Water Department was quite fortunate in that its first attempt at ratemaking in 1952, without the availability of the new accounting system, was upheld by the court.

At the present time, charter requirements for budgeting are the same for all departments, and budget appropriations are based upon lump sums for such items as personnel, purchase of services and materials, and debt service, rather than on the standard items in water works accounting practice. As a result of this—and also because of the requirement that the department operates on a cash rather than an accrual basis—it is necessary that two separate sets of books be kept.

Customer Service

It was quite evident in 1952 that an entirely new basis for customer relations had to be established. It is no criticism of previous practices to say that the Water Bureau in most instances operated as any other governmental agency and without the service spirit which is the mark of a good utility. Quite early in the planning stage, a new customer service division was organized. It was given a chief who was thoroughly imbued with the idea of service, and its personnel were thoroughly trained and indoctrinated with this same idea. Persons who telephone for information or call at the office are handled by an employee who stays with the customer until the matter is settled. This is done even though, in many cases, it is necessary to contact other departments. Complaints or requests for information which need field investigation are handled promptly by uni-

formed inspectors, most of whom travel in radio-equipped cars.

Public Relations

The department has been fully aware of the importance of a good public relations program. At the present time, the general attitude is such that a program of paid advertising in newspapers, radio, or TV is almost impossible. On the other hand, the department has used free time made available by radio and TV stations, and embraces every opportunity to tell of its program through news articles and special features. Trips to plants are encouraged, although not utilized to the fullest extent. Department speakers are available to any group, and each speaking engagement is used partly to tell the overall story of the department.

Physical Plant

Full recognition was given to the problem of modernizing and rebuilding the physical plant. Even the best personnel cannot turn out good water in adequate amounts and at adequate pressures unless they have reasonably good facilities which are adequately maintained. In Philadelphia, the four filter plants, with a capacity of approximately 400 mgd, were built in the decade between 1900 and 1910. When first built, these slow sand plants were fine examples of the water engineers' art, but they had aged and deteriorated physically, without proper maintenance, and did not have the ability of modern rapid sand plants to turn out the quality of water which modern citizens demand. In addition, they were strained to capacity to turn out enough water during hot summer days.

Philadelphia is now building a new modern rapid sand treatment plant at Torresdale, within the city limits. The plant has a capacity of 282 mgd at the rate of 2 gpm per square foot, and will replace the old slow sand plant at this location. Work on this $20,000,000 project is now about a third completed, and it will be ready for operation in 1959.

At Queen Lane, a new pretreatment building, together with mixing and coagulating basins, was placed in operation early this year, and work is now starting on the reconstruction of rapid sand filters for this 120-mgd plant. The filters are being rebuilt in the same location as the old filters, and the plant will remain in operation during construction.

At the 70-mgd Belmont plant, design work is starting for the construction of modern rapid sand filters. This will raise the plant capacity to 85 mgd. Construction will start in 1957.

By 1960, when all three of these plants are finished and in operation and the small 25-mgd plant at Roxborough is abandoned, Philadelphia will have completely new rapid sand treatment plants for its entire water supply.

Work has also been progressing on modernization of pumping stations. Philadelphia has had steam pumping from the time the first plant was built in 1799—including the famous engine of Oliver Evans which blew up in 1818—until the last steam plant was taken out of service in September 1954. Some of the electrically driven pumps are 30 years old, and new plans call for the replacement of motors and pumps within the next 5 years, thus completely modernizing this phase of the operation.

Modernization of the distribution system is under way. The job is so

big and complex that it is planned to continue for at least the next 25 years. Wooden water pipes were used for the first 20 years of operation at the water works in Philadelphia, but these were abandoned and iron pipes were used beginning about 1820. Many of these old pipes are still in use, mostly in the central area of the city, and many are inadequate in size. Their shallow depth creates trouble under modern heavy traffic, however, and accumulation of dirt and corrosion in the pipes restricts flow and causes difficulty with dirty water. The complex distribution system—which is really twelve main systems and many subsystems—also needs strengthening, and this will consist of construction of large 36-in. and 48-in. lines to bring additional water into many areas.

In other sections of the city, especially on high ground, pressures are maintained only by pumping stations with no storage capacity. Elevated tanks are now under construction and others are planned for the next 5 years.

One of the steps which has been taken to help in the design and redesign of the distribution system has been the purchase of a McIlroy Fluid Network Analyzer.* It was purchased primarily for the use of the engineering bureau in the design of new trunk mains, both in new and old sections of the city. In addition, it has many uses in connection with changes and regulations in the distribution system.

Another step in modernizing the system will be taken later in 1956 when work is begun on a modern load-dispatching system. Money has been appropriated and specifications are now being written for the equipment and communication lines which will concentrate and automatically record the status of all important factors in the system. Beyond that, the magic of "automation" is under consideration and there is preliminary planning for as much automatic control and operation as possible.

* Manufactured by the Standard Electric Time Co., Springfield, Mass.

Personnel

An attempt has been made to bring adequate management and supervision into the divisions which have immediate charge of the operations of the water works. Some additional personnel are still required, but a start has been made in reorganization and in getting the best of service for the amount of money expended.

Meters and Metering

The reorganization of the meter repair shop is an outstanding example of efficient planning. Perhaps the accomplishment in this division appears so imposing because there was so much to do: there is no doubt that improvements had to be made in a division having a backlog of 30,000–40,000 meters awaiting repair and thousands more on customers' premises not registering. G. E. Arnold gives an account of the work done in this division (*3*).

Another important phase of the operation of the Philadelphia water works concerns universal metering of the system. Metering had started in Philadelphia in 1901, when authority was given to require meters where there was a large usage of water and to permit their installation in residential properties at the request of the owners.

In 1917 a full schedule of meter charges was fixed, and in 1918 an ordinance required that all properties built after that date must be metered. The net result was that all commercial and

industrial properties and all residential properties built after 1918 or connections made after 1918 were all metered.

For many years there was talk of requiring residences built prior to 1918 to install meters, but nothing resulted from these discussions. In 1952, it was decided that all properties should be metered. The number of unmetered properties was then about 180,000.

Regulations were adopted requiring all properties to be metered immediately, and, although this was supported by the community in general, it ran into all sorts of objections. The matter was complicated by the fact that owners of existing metered properties had paid for the meters themselves. Whenever a meter was repaired, the same meter was returned to the property and the cost of repairs billed against that property. (The rate structure which became effective in 1953 abandoned this individual billing for repairs, and the cost is now included in the annual minimum charge.)

A group of persons took the matter to court, and the entire program was delayed for about 2 years while the matter was argued in the lower court and the Supreme Court of Pennsylvania. The decision of the lower court (*4*) upheld by the Supreme Court of Pennsylvania, supported the entire position of the city and confirmed the city's powers to require all properties to be metered and to do any necessary work preparatory to the setting of the meters, if such work is not done by the owners. The decision also confirmed the right of the city to substitute a new or reconditioned meter at any time to replace one which was not functioning properly.

As a result, the universal metering program got under way fully in 1955 and by the end of 1956 the program will be substantially complete. G. E. Arnold discusses the details of the actual work at length (*3*).

Billing

One of the real problems in the overall reorganization of the water service is the matter of meter reading and billing. As indicated earlier, the charter framers placed the responsibility for this work in the Department of Collections, whose functions also include the collection of real estate taxes, wage tax, and a host of miscellaneous taxes and charges. Prior to 1952, the past record and experience for meter reading and billing had not been good, and it was definitely related to the correspondingly poor record on meter repairs.

In 4 years, much work has been done to improve the system of meter reading and billing. Unfortunately, the press of other work in the Department of Collections has not made it possible to do the things which are necessary to modernize this function.

The Water Department believes that the full and final solution is to transfer functions of meter reading and billing to the Water Department, which will follow the custom of private water utilities and other well run public water utilities. It appears that the public accepts this as the proper course of events, and, in public comments and criticisms of billing and meter reading, people continually refer to the practices of the Water Department.

Philadelphia's past practice in billing has been to send one annual bill covering the minimum charge for the calendar year, and, except in the case of heavy users, to send one bill each year for water used above the minimum allowance. All minimum bills

are mailed at the same time, generally in May or June, and bills for water used above the minimum allowance are mailed within a period extending from April to October. These latter bills have been given the name of "excess" bills in Philadelphia, and this has caused trouble, because many people think that there is something wrong with using water above the minimum allowance. This allowance for residential properties with a ⅝-in. meter is 4,000 cu feet of water annually.

As part of the overall future program, the Water Department is advocating the transfer of billing and meter reading to the Water Department, and the establishment of cycle billing with a minimum of two meter readings during the year.

Conclusions

For those who have had a part in reorganizing Philadelphia's utility management, the past 4 years have been a thrilling experience in transferring the water and sewer services from a general governmental operation to a self-sustaining utility. Not only have there been management problems to meet and solve in setting up this utility within the general framework of the city government, but there has also been the opportunity to undertake physical projects as the complete renewal and modernization of treatment plants for the city. There have been difficult problems in public relations involving not only the public at large but also the acceptance by persons at all levels of government of the status of the new department, with its separate funds and other separate functions and responsibilities.

Some of the problems which have been partly solved need further solution. Others, such as the matter of meter reading and billing, have just been approached and their solution is hoped for in the immediate future. Other problems, such as the setting up of funds for depreciation, are long-range in nature and no immediate solution is seen.

References

1. *Monaghan* v. *City of Philadelphia,* No. 4473, Philadelphia, Pa. (Dec. 1952).
2. *Manual of Water Works Accounting.* Municipal Finance Officers Assn. & American Water Works Assn., New York, N. Y. (1938).
3. Arnold, G. E. Universal Metering and Meter Repair in Philadelphia. *Jour. AWWA,* **48**:1209 (Oct. 1956).
4. *Miehle* v. *City of Philadelphia,* No. 8880, Philadelphia, Pa. (Mar. 1953).

Universal Metering and Meter Repair at Philadelphia

Gerald E. Arnold

A paper presented on May 9, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Gerald E. Arnold, Gen. Supt., Water Dept., Philadelphia, Pa.

PRIOR to 1918 there were few water meters in Philadelphia. At that time it was decided that metering should be initiated and an ordinance of the City Council in that year required that all new construction built in Philadelphia after that date be equipped with a water meter on the water service line. Another later ordinance required that all commercial and industrial establishments be metered, regardless of age. This ordinance was retroactive; the first was not. By 1952 there were more than 500,000 active water services in Philadelphia of which about 320,000 were metered. All of the unmetered services were in residences built before 1918 and were therefore scattered throughout the city. During 1952 it was decided to complete the metering of the entire city. This meant installing water meters on the 180,000 water service lines then unmetered.

Law Suit

It was also decided at this time that all water meters would thereafter be installed or removed only by water department employees. (Prior to this time meters had been installed by plumbers, with the water department employees engaged only in removal or reinstallation when meters required repairs.) This decision was not popular in some areas and resulted in a law suit.

The suit was filed against the city officials, particularly the water commissioner, and contended that the city was depriving plumbers of business enterprise by insisting that consumers buy meters only from the city, that the requirements of the water department regulation on universal metering were discriminatory, and that the city was violating both the Constitution of the United States and that of the Commonwealth of Pennsylvania.

The trial occupied several days of testimony and became quite involved. The lower court handed down its decision of Jun. 17, 1954, reciting 30 findings of fact, all of which were favorable to the position of the city as defendant in the case.

The decision held that the water department had full authority to require metering of all consumers' premises, that the proposed plan of metering was not discriminatory or unjust, that the water department had a right to purchase and resell meters to consumers, and that the utility should handle meters as a part of standard utility practice. Removing and replacing water meters was deemed a duty of the water department because the department's employees were considered capable and

could therefore avoid contaminating the water supply or creating hazardous plumbing conditions. A yoke or horn was found to be a useful device and the city was deemed justified in requiring its use.

Probably the most outstanding finding of the court was in connection with ownership of the meters. That decision was as follows:

> 29. Under the city's proposed universal metering program whereby meters are to be purchased by and installed by the city such meters will be and remain the property of the city of Philadelphia and be a part of the city's water supply facilities. The fact that the cost of such meters and the installation thereof is to be directly passed on to the consumer does not constitute such meters the personal property of the consumer.
>
> 30. In the absence of evidence of intention to the contrary, the annexation of a water meter to the city's water supply facilities constitutes a transfer of possession, dominion, control, and title to such water meter by the consumer to the city of Philadelphia.

The decision of the lower court was appealed to the state supreme court and was heard by the high court in January 1955. The state supreme court handed down a decision upholding in full the findings of the lower court.

Planning and Inspection

The first step in the universal-metering program was to set up an organization to review the records and establish a procedure to follow. From the billing records in the department of collections, the names and addresses of the owners of unmetered premises in the city were obtained and file cards were prepared.

The next step was to establish a preinspection routine for all of the unmetered properties. A preinspection form, shown in Fig. 1, was prepared. This form was filled out in quadruplicate by the inspector when the preinspection of each premise was made.

The preinspection served several useful purposes. First, it notified the owner or occupant in person that he would be required to install a water meter and gave him an opportunity to ask questions which could be answered by the inspector. Second, it gave the department a complete record of the size, type, and condition of the piping in which the meter was to be installed. Third, it gave both the department and the owner information regarding any repiping which had to be done as part of the meter installation. At the time the preinspection was made, the inspector hung a red tag on the piping at the point where the meter was to be installed.

One copy of the preinspection form was left with the occupant or mailed to the owner immediately after the preinspection was completed. The owner was then given the choice of having his own plumber install the necessary fittings and connections for the water meter or, by returning the form with the proper indication, having the city do the work under contract at the consumer's expense. About 78 per cent of the property owners returned the form requesting the city to do the preliminary work; the balance was done by private plumbers. If rearrangement of the piping was necessary, the owner was advised to have it done by his plumber. Under its contract the city installed only a horn or yoke, with or without a valve.

Installation

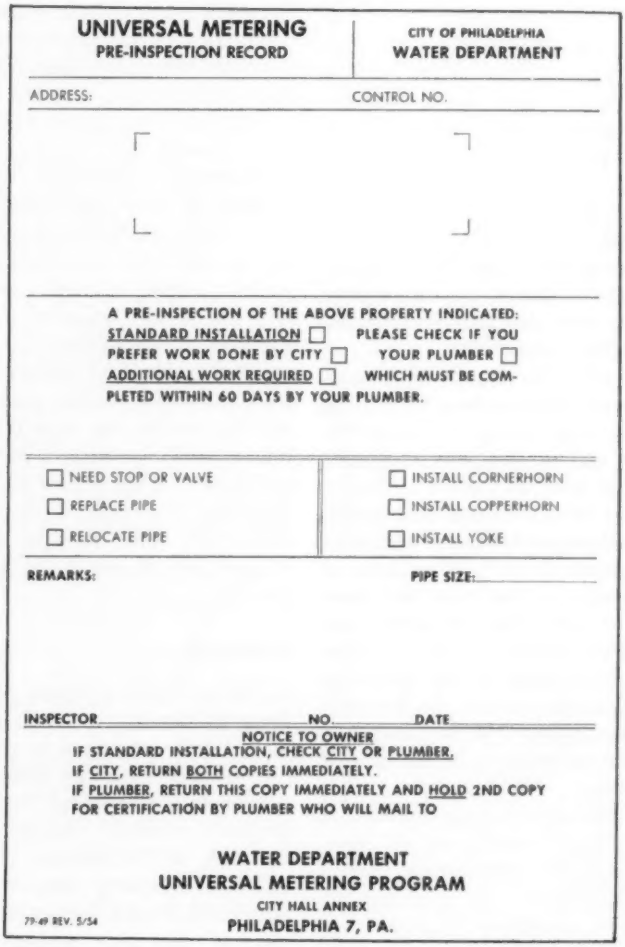
With the above information in hand, the city proceeded to purchase the necessary horns and yokes and to award contracts for their installation in consumers' premises. Three such contracts have been awarded, two of which are now completed. A fourth contract will be awarded in the near future, completing the preliminary piping work in almost the entire city. Each of the contracts was for approximately 25,000 installations.

Because all of the installations were to be made in houses where the piping was old, it was desired to make the installation simple, thus disturbing the old piping as little as possible. A special type of horn or yoke was developed in the department and manufactured to specifications. This horn or yoke is similar to the standard horn made by several manufacturers for holding water meters, except that it is equipped with compression couplings which permit the horn to be installed on existing piping without threading the pipe, or soldering it in the case of copper tubing. This made possible quick and economical installations. It also kept blow torches out of basements, where they would have been a serious fire menace. In installing the horn it was necessary to make only two cuts in the pipe. This was done with a wheel cutter or hack saw. The horn was slipped into place and secured by the tightening of two nuts. To hold the compression coupling firmly in place, an Allen screw was used on iron pipe; on copper pipe, a split clamp was attached to the compression coupling nut. The installation could readily be made in a few minutes. The contract for the installation of the horns and yokes was done on a unit basis and the contractor was furnished all material including the horn and the spacer pipe, which he left in the horn in place of the meter.

After the installation was made, the water was turned on and normal water consumption continued for a period of at least 10 days before the meter was set. This permitted a thorough flushing of the new connections and prevented clogging of meters which otherwise might have occurred. The meters were set by water department employees rather than by plumbers or contractors. At the time the meter was set, the spacer pipe was picked up so that it could be reused on a later installation. Final inspection of the installation was made by the water department's meter installer at the time he installed the meter and sealed it on the line.

Financing

The universal-metering program was financed through a bond issue. The bond funds were used to purchase the meters and make the installation, the total cost of which was charged to the property owners. Because all meters installed in Philadelphia prior to the universal-metering program had been bought and paid for by the property owners, the only equitable way to handle universal metering was to have all new meters installed at the consumers' expense. Upon completion of each installation, a bill was prepared and presented to the property owner. This was to be paid within 30 days or in three equal installments over a period of 2 years. A charge of 6 per cent was made on the deferred payments. The cost of a standard installation, including the preinspection, overhead,



UNIVERSAL METERING
PRE-INSPECTION RECORD

CITY OF PHILADELPHIA
WATER DEPARTMENT

ADDRESS: CONTROL NO.

A PRE-INSPECTION OF THE ABOVE PROPERTY INDICATED:
STANDARD INSTALLATION ☐ PLEASE CHECK IF YOU
PREFER WORK DONE BY CITY ☐ YOUR PLUMBER ☐
ADDITIONAL WORK REQUIRED ☐ WHICH MUST BE COMPLETED WITHIN 60 DAYS BY YOUR PLUMBER.

☐ NEED STOP OR VALVE
☐ REPLACE PIPE
☐ RELOCATE PIPE
☐ INSTALL CORNERHORN
☐ INSTALL COPPERHORN
☐ INSTALL YOKE

REMARKS: PIPE SIZE:

INSPECTOR NO. DATE

NOTICE TO OWNER
IF STANDARD INSTALLATION, CHECK CITY OR PLUMBER.
IF CITY, RETURN BOTH COPIES IMMEDIATELY.
IF PLUMBER, RETURN THIS COPY IMMEDIATELY AND HOLD 2ND COPY FOR CERTIFICATION BY PLUMBER WHO WILL MAIL TO

WATER DEPARTMENT
UNIVERSAL METERING PROGRAM
CITY HALL ANNEX
PHILADELPHIA 7, PA.

77-49 REV. 5/54

Fig. 1. Preinspection Card for Universal-metering Program

horn, labor, and a meter, was about $35.

Following the law suit and final decision of the court, the universal-metering program got into full swing. During the court proceedings, no active work was carried on except for the preinspections, which were continued throughout the period of litigation.

Completing the Program

As of May 1956, more than 100,000 meters had been placed, and it is contemplated that the entire city will be metered by Jan. 1, 1957. It is believed that Philadelphia is the first major city to undertake a large-scale universal-metering program of this type, and the author feels that the program is being

successfully accomplished and will have satisfactory results. To date, there have been comparatively few complaints on the part of consumers. Some unusual situations have had to be handled individually, of course, and there have been some headaches, but, because of the thorough advance planning and the correct direction of the program, the work has gone forward without undue difficulty.

Reorganizing Meter Repair

About 3 years ago, an entirely new concept of water meter repair was instituted in Philadelphia. This program has resulted in a vast increase in the number of meters repaired without increasing the number of personnel required and at a considerable reduction in overall cost.

During 1952, there were more than 30,000 meters still in service which were known to be in bad order. Most of these had been reported as nonregistering meters by the meter readers. In addition to the 30,000 meters still in consumers' premises, there were about 5,000 meters in the meter shop awaiting repair. These were being repaired at the rate of about 400 a week. Each repairman in the shop customarily handled one meter at a time, doing the entire cleaning and repairing operation himself.

Late in 1952 a firm of industrial consultants was employed to review the operation of the meter shop and to recommend improvements. Following its survey of the situation, the meter shop was completely reorganized, new equipment was purchased, the employees were placed on an incentive pay plan, and overall operations were materially increased.

Procedure

The best way to describe the present procedure is to follow a typical water meter through the shop describing what is done along the way. As the meters are brought in, the necessary records are taken from the shop tag which accompanies the meter. The meters then go to the breakdown bench where a special jig has been provided to hold the meter firmly in an inverted position while the bolts are removed from the frost bottom with a power-operated electric torque wrench known as an impact wrench. The impact wrench is suspended on counterweights over the breakdown bench and quickly removes the bottom bolts from the meter even though they may be rusted in place. After removal of the frost bottom, the major parts of the meter are removed and taken apart. The meter is then given a quick water wash with a scrubbing brush to remove the mud and prepare it for final cleaning.

Further disassembly of the meter is then accomplished and all of the meter parts are put in a square steel pan, all the parts for an individual meter being kept together. The chamber and main case and all other parts of the meter that have to be thoroughly cleaned are then dipped in an acid solution to remove the scale and crusted deposits. Following the acid, these parts are given three rinses, one of which is with an alkali solution to offset the effect of the acid. All the meter parts are then replaced in the steel pan, and the pan is passed to the inspection bench.

Here an inspector carefully examines each part of the meter to determine whether it can be reused or must be discarded. He has before him a meter checkoff list, shown in Fig. 2,

which has on it the name of each part of the meter. As he discards the meter part, he checks that line on the checkoff list. The checkoff list then goes into the steel pan with the remaining parts of the meter, and the pan is placed on a conveyor which runs directly into the stockroom.

The stockroom clerk takes the checkoff list and places in the pan a part for each one checked on the list. The stockroom clerk then keeps these checkoff sheets until the end of the day and totals them for inventory records.

The complete meter with the old and new parts now in the pan rolls on the conveyor to the window of the stockroom where the meter repairmen obtain the meters. Each man at the repair bench takes from the window a pan containing parts for a complete meter. He takes the pan to his work bench and assembles the meter, giving it quick water-and-air test at his bench to see that it is functioning. The completed meter in its steel pan is then placed on a conveyor which carries the meter to the test rack.

Personnel

Meters are tested in standard fashion by employees especially qualified to conduct this testing. There are a total of eight lines in the test area operated by two men. The flow of water into the calibrated tanks is controlled by solenoid valves which are activated by electronic controls in the calibrated tanks. Thus, when one of the test lines completes its run, the water level in the tank will automatically close the solenoid valve at the proper quantity. This relieves the operator of the necessity of watching carefully for the end point of the test and enables him to handle four lines of meters at one time.

METER CHECK-OFF LIST		WATER DEPARTMENT METER DIVISION
METER		DATE
	S. B. BEARING	
	BOLTS AND NUTS	
	BOTTOM	
	REGISTER BOX ONLY	
	REGISTER BOX COMPLETE	
	TOP CASE	
	CHAMBER	
	SPLIT COLLAR	
	REGISTER BOX COVER	
	REGISTER CUP	
	DIAPHRAGM	
	DISC	
	REGISTER FACE	
	GASKET	
	REGISTER CUP GASKET	
	COMP. GLAND	
	REGISTER GLASS	
	CHAMBER INSERT	
	CLAMP NUT	
	S. B. NUT	
	S. B. BEARING NUT	
	S. B. CLAMP NUT	
	REGISTER BOX PIN	
	REGISTER	
	SPLIT CONTROL RING	
	THRUST ROLLER	
	SCREEN	
	SCREWS (REG. CAP)	
	SCREWS (CHAMBER)	
	SCREWS (CHAMBER HOLDING)	
	SCREWS (REG. CUP)	
	SCREWS (DIAPHRAGM)	
	SCREWS (HEX TRAIN)	
	SCREWS (TRAIN)	
	DISC SPINDLE	
	S. B. SPINDLE	
	TRAIN	
	WASHER	
	S. B. BEARING WASHER	
	REGISTER SPRING	

Fig. 2. Meter Checkoff List for Universal-metering Program

After testing, the meters are placed in wooden boxes holding five meters each and are placed on another conveyor which carries them directly to the paint spray booth. Here the meters are given a coat of bronze-colored paint, and they come out looking very

much like new meters. As a final step, the meters are racked up on shelves to be scheduled for reinstallation in consumers' premises.

In summary, the meters move through the shop on a production line basis. No one has to carry a water meter more than 5 or 10 ft. They move from one step in the process to another by gravity conveyors, each meter being kept to itself in its steel pan. Each step in the operation is performed by one man who is especially trained and qualified for that step. More than 1,400 meters a week pass through the shop, with the same number of employees that used to service 400 a week.

New Salary Plan

One of the important developments in connection with the meter shop is the establishment of the incentive pay plan. Time studies were carefully made of each operation in the meter shop and a standard was established for that operation.

Each man working in the shop receives this base pay whether he performs in accordance with the full standard or not. If the repairman exceeds the standard, he receives additional pay in accordance with the standard minutes prescribed for each operation. Thus, by working diligently at his job, the repairman is able to earn additional pay.

Because all of the operations in the shop are on a production line basis, if one of the men in the line does not do his full share of the repair work, the line slows down and all of the men in the line lose at least a portion of their incentive pay. This has been instrumental in increasing the rate of operation in the shop, and is probably as responsible as is the new equipment for the marked increase in production. If a man continually falls below the standard, he is removed from his job and given another assignment or discharged.

The labor union and the Civil Service Commission approved the incentive pay plan after some persuasion. The union was willing to accept it because it guaranteed a minimum wage on a day-by-day basis, whether or not the man met the minimum standards. The standards have been revised once since the incentive pay plan was instituted, raising the standards in some instances, lowering them in others to adjust for conditions which developed as a result of the increased operating schedule. Even the upward revision of standards was accepted by the union.

So far as is known, this is the only incentive pay plan in operation in a municipal water system, and it is working satisfactorily. The men earn an average of an added 20 per cent of their base pay as a result of the incentive plan, and are doing an efficient job of repairing meters. Quality control is maintained by means of the testing. Any meter failing to meet the test is returned to the man who assembled it, and he must correct the fault without incentive credit.

Large meters are not handled under the incentive pay plan nor are they handled on a production line basis. Because of the wide variation in work that has to be done on large meters, particularly compound meters, a production line method cannot be used. The men who work on large meters are given a higher classification than those on the small meters, and their pay rate is higher.

Field installers also work on the incentive pay plan, and are given certain

time credits for each field operation including such items as repacking a stuffing box, removing an old meter and placing a new one, or making other minor repairs in the field. They even get credit for a no-response when there is no one home, and the work cannot be done. A reasonable allowance is made for driving time from one job to another.

Altogether, the revised schedule and new method of operation have tripled the number of meter repairs made in the shop and have resulted in a vast improvement in field operations. Within 2 years after the incentive pay plan was instituted and the new procedure in the shop started, the backlog of meter complaints was wiped out, until, today, the meter shop is practically current with service work.

Prior to 1953 meters had never been brought into the shop except on complaint, indicating that they had either stopped or were leaking or in bad order. As a result, there are many thousands of meters in the system which have never been repaired. In 1954, a rotation schedule was established under which all meters are to be brought into the shop for repair at least once in 10 years. It is felt that this rotation schedule will result in better metering of the water and a definite increase in revenue. Many of the old meters brought in are found not to register at the low flows. Because the meters had been neglected, the cost of repairs is higher than it would be for meters kept in good condition. The labor is very little more in cost, but the parts are running considerably above the average because of the faulty meters. At present, the labor costs for repairing a ⅝-in. meter are $1.75. Before the new plan was instituted, the cost of the same repairs was $3.50.

Conclusion

Together with the universal-metering program and the arrangement of the meter repair shop, the incentive pay plan, and the policy of rotating meters, there has been a decided improvement in the overall metering practice in Philadelphia. It is hoped that the procedure outlined above will be helpful to other water works men in improving metering practice.

Practical Metering Procedure at Waukesha

Joseph H. Kuranz

A paper presented on Sep. 22, 1955, at the Wisconsin Section Meeting, Milwaukee, Wis., by Joseph H. Kuranz, Asst. Mgr. and Engr., Waukesha Water Utility, Waukesha, Wis.

CONSIDERATIONS of water metering problems are frequently discussed in connection with the distribution program. One might ask just what metering has to do with the many complexities of the distribution system other than to indicate the amounts of water delivered to customers. The meter, of course, can be likened to a cash register and the function it performs in a market, but the cash register in a market does not aid directly in solving the merchandising problems. This is where the meter differs: the meter serves many additional functions, some of which directly affect the efficiency of the distribution system. Leaks in service lines, for instance, can be more readily located, thereby affording maximum protection to the customers' property against possible water damage. Metering is the most practical procedure for controlling excessive waste, and selling water through meters is the logical and fair way of doing business because it protects the customer against discriminating practices. Water consumption data is essential in establishing new water rates, and metering all services is the only practical way of obtaining information; in this way the utility will have a good check on the amount of water sold. By comparison with master meter readings, the percentage of water accounted for can be readily calculated.

These are but a few of the many additional functions which the meter performs.

Percentage of Efficiency

The last item mentioned above, the percentage of efficiency, is the function by which metering becomes most important as an ally to the distribution system. The basic formula for percentage of efficiency is $\frac{\text{output}}{\text{input}} \times 100$. This may be restated:

$$\text{percentage of water accounted for} = \frac{\text{total water through all service meters}}{\text{total water through all master meters}} \times 100.$$

By simply substituting in the above formula, the utility manager may calculate the water being accounted for and the deficit assumed to be waste. This statement is an oversimplification, however, for first of all it must be ascertained that the data used in the formula are correct and, in order to be reasonably sure of this, a very carefully planned and executed metering program must be established. If this is not done, all sorts of misleading information will result.

Say, for example, that the portion accounted for is 70 per cent. The first impression would naturally be that 30

per cent of the water is being lost through leakage. If some of the leaks are found and repaired, raising the 70 per cent to 90 per cent, for instance, then the distribution system is improved by 20 per cent because the water pumped into it will be decreased by that amount. This analogy can be carried further and actually used in calculations to determine sizes of new mains which are being developed. On the other hand, the master meters may have been overregistering, which could also give the 70 per cent registration. In this case a thorough leak survey may not be warranted, and, if conducted, may result in no appreciable improvement in the accounted-for water. The possibility of the second situation happening can be eliminated by merely assuming that the unaccounted-for water is not necessarily all waste and then, from this basic assumption, making every effort to prove just how much does consist of wasted water.

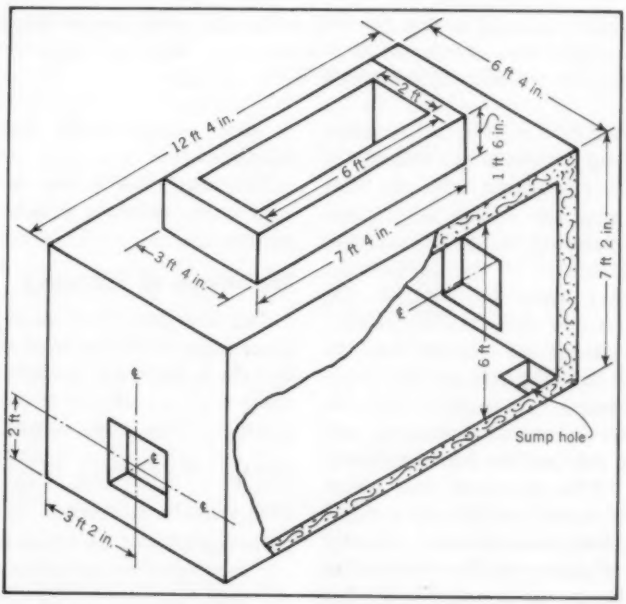


Fig. 1. Venturi Meter Vault

The vault is of 8-in. thick concrete, with a 6-in. thick concrete floor pitched if a sump is used. The top of the combing is recessed 1¼ in. × ¼ in. to provide a seat for cover, which should be a 26½-in. × 74½-in. × ¼-in. steel plate, with pickup holes in the cover. Grade should be finished to top of combing. Dimensions given may be altered to suit needs.

The only practical way to accomplish this is by accurately metering all services and all sources of supply. Not many years ago the question was *whether* to meter; today, however, it is *how* to meter.

Master Meters

Going back to the basic formula, the first unknown to be found is "total water through all master meters." This can best be accomplished by main-line metering of all water pumped into the distribution system. Main-line meters may be divided into several basic types, the most common of which are venturi meters (venturi tube, flow nozzle, and thin-plate nozzle); turbine or propeller meters; and positive-displacement meters.

Before a metering system is selected, however, several factors must be taken into consideration if the most efficient arrangement is to be obtained. These factors are accuracy, reliability, pressure loss, installation, capacity change, and initial cost. In this discussion, the primary interest is accuracy. The other items are listed in order of their importance.

Citing a specific example, Waukesha, Wis., has in operation five deep well pumping stations. All of Waukesha's well pumps are designed to pump into clear-water basins where the water is aerated and then pumped by booster pumps into the distribution system. All water discharged through the booster pumps into the system is metered. Both venturi and the propeller type of meters are employed in the Waukesha system, and, as far as accuracy is concerned, both types are very nearly equal and can be adjusted to give 100 per cent registration when installation and calibration is done under suitable conditions. Because of small inaccuracies introduced by the register, and other mechanisms, however, manufacturers normally extend a conservative guarantee that the reading will be within 2 per cent of 100, plus or minus.

In order to assure accurate metering, the manufacturers installations requirements and other sound metering practices must be adhered to. The advantages and disadvantages of the two basic types used at Waukesha will not be discussed here, as that is a study in itself. There are some basic requirements that must be fulfilled by either type, however.

First, the installation must conform to the manufacturer's instruction and should provide for easy access for removal, service, and repair. Installation requirements for the average propeller type of meter are relatively simple, but the venturi meter usually requires more space. That may not be true in every installation, however, because the exact locations depend on individual conditions and preferences. In Waukesha, the pumping stations were not laid out to provide for the venturi meters to be inside the buildings proper and an outside vault was designed to meet the requirements, Figure 1 shows a typical vault which can readily be modified to suit other similar installations. The overall dimensions, of course, will depend upon such factors as the size of the meter and the geographical location of the pumping station.

Meter Checking

In order to obtain 100 per cent registration, plus or minus a few tenths of a per cent, some means must be provided to accurately check the meters. There are several ways in which this can be accomplished, and the simplest and most practical is to use a calibrated tank of some sort. In Waukesha, a calibrated section of the adjacent clear-water basin is used. The volume of this section is large enough to enable the test to last approximately

1 hr with the booster pump discharging at a normal rate. Figure 2 shows how the clear basin or reservoir, with the use of hook gages, may serve as a test tank. This is the most simple and accurate way known to conduct this type of test.

A modern adaptation of the hook gage is shown in Fig. 3. This arrangement has several advantages over that shown in Fig. 2 in that it is somewhat easier to use and the entire test can be conducted by one man. With a standard hook gage, two men are usually required.

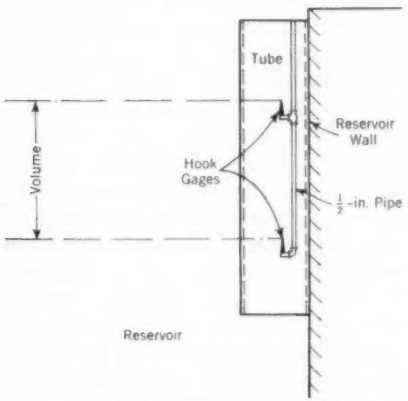


Fig. 2. Simple Hook Gage

The water wave–dampener tube is to be of sufficient diameter to permit insertion of a ½-in. pipe and hook gage assembly and to allow a testing crew to lower a drop light for observations. The tube should be open at top and bottom and of metal, concrete, or other suitable material. The displacement in the calibrated test section should be large enough to permit test run to last about 1 hr.

Waukesha's master meters are checked once a year during December and January. Three tests are run on each meter and the average is found. The meters are then cleaned, serviced, and adjusted, after which three new tests are made and the average again found. The averages are all used in computing the composite registration rate of the master meters. This can be shown by referring to a typical master meter–testing program such as is conducted once a year in Waukesha. Tables 1 and 2 give the results of such a program for the year 1954. Using the variations from 100 per cent given in Table 1, the over- or under-registration for each station can be computed as follows:

166.043 mil gal × 0.0055
= + 913,237 gal,
296.746 mil gal × 0.0099
= + 2,937,785 gal,
280.165 mil gal × 0.0106
= − 2,969,749 gal, and
263.032 mil gal × 0.0089
= + 2,340,985 gal.

TABLE 1

Report on Master Meter Test, 1954

Date of Test*	Avg for 3 Tests *per cent*	Registration *gpm*
North Street Meter—Venturi Type		
Jan. 7, 1954	100.31	675
Dec. 13, 1954	100.8	640
Baxter Street Meter—Venturi Type		
Jan. 6, 1954	99.48	875
Dec. 15, 1954	102.5	867
Newhall Avenue Meter—Venturi Type		
Jan. 5, 1954	97.09	874
Dec. 14, 1954	100.8	900
Moreland Avenue Meter—Propeller Type		
Dec. 29, 1953	100.68	887
Dec. 16, 1954	101.1	869

* The first test shown for each meter was after cleaning, servicing, and adjusting.

Total over-registration can be computed for all four stations to equal 3,222,258 gal. The percentage of over-registration is $\frac{3,222,258}{1,005,986,000}$, or 0.32 per cent. This composite over-registration of 0.32 per cent must be added to the percentage of water accounted for in order to determine the true yearly percentage. This would be

$$\frac{\text{total water through all service meters}}{\text{total water through all master meters}} \times 100 + 0.32$$

or, for 1954,

$$\frac{\text{total water through all service meters}}{1,005,986,000} \times 100 + 0.32$$

From the foregoing test, several interesting conclusions can be drawn. First, it is apparent that the venturi meters have a tendency toward over-registering. This is normal for a venturi meter and the test will further indicate that in Waukesha the "gain" will be anywhere from $\frac{1}{2}$ per cent to nearly 4 per cent over-registration in 1 year. In order to minimize this over-registration, the venturi tubes are removed and cleaned yearly. Between $\frac{1}{64}$- and $\frac{1}{32}$-in. build-up has been observed in the tubes after 1 year of service, accounting for the comparatively large range in over-registration. To control this tendency, the meters are adjusted to under-register at the beginning of the year. The result will be a composite registration very close to 100 per cent. Once a program such as the one given here is inaugurated and carried out on a yearly basis, it will be found that the meters can be adjusted so that the average registration is nearly perfect. The pumpage is greater during the summer than in the winter, of course, and it may seem that the averages as taken will not be mathematically correct. For all practical purposes, however, any error introduced in that manner may be assumed as negligible. The denominator for the formula "percentage water accounted for" can now be used with the assurance that good metering procedures were involved in obtaining it.

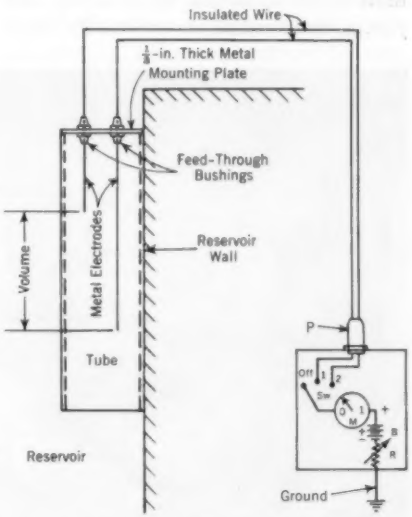


Fig. 3. Adaptation of Hook Gage

Lettered symbols indicate the following: Sw—*three-position rotary switch;* M—*0–1-mm gage;* B—*45–90-v battery;* R—*1-megohm variable resistor;* and P—*removable two-contact miniature plug. The entire meter assembly may be mounted inside of a small portable cabinet to facilitate use at additional stations.*

Service Meters

The second unknown in the equation is the numerator, or "the total water through all service meters." This will be the most difficult phase of the project because, to obtain a figure that is anywhere near correct, all services must be metered: universal metering is a must. In Waukesha, lib-

erally stated, every use of water is metered, whether the utility gets paid for the water or not. Water uses that may pass even a diligent manager do not circumvent Waukesha's record books. A few of these often overlooked users are: city drinking fountains, municipal sewer flushing, water used from hydrants by building and paving contractors, as well as the city's own usage for new mains and service trench flushing and private fire protection services or sprinkler systems. Water used for fire-fighting purposes is not metered. After each fire, however, the fire chief notifies the water utility of the estimated amounts used, after which it is duly recorded. Private fire lines do not use water unless a fire occurs, so no meter is inserted into the line. The city does require that some type of automatic electric flow alarm be installed, however, and it makes its own periodical inspections of the fire lines to insure against surreptitious use as well as to protect the customer against possible violation of fire underwriter regulations.

Service metering is a complex project and there are no simple solutions to its problems. Many variables, some controllable, others not, enter into a metering program, but all water utilities must solve approximately the same fundamental problems if good results are to be anticipated. Several basic items encountered in all metering systems, whether large or small, are ownership and location of meters, selecting the right meter, type of setting,

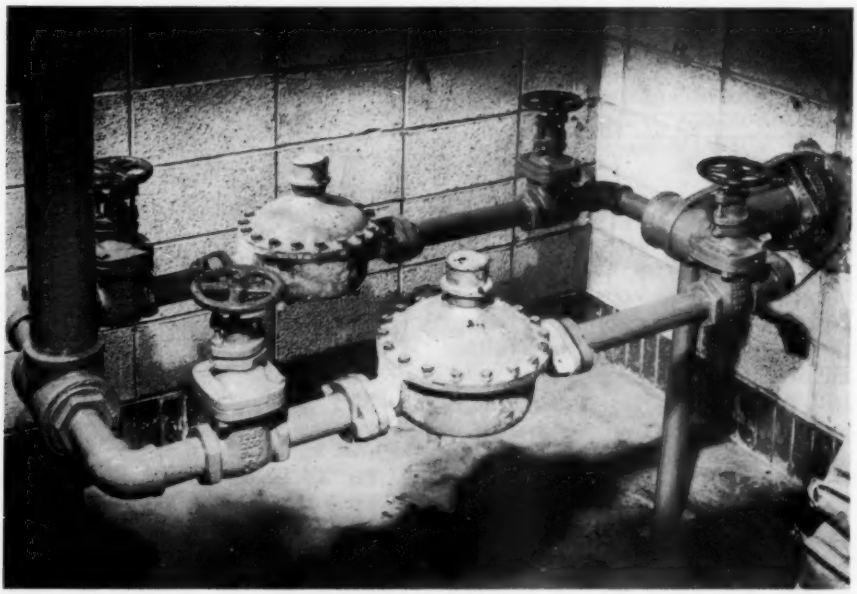


Fig. 4. Battery Meters

To facilitate meter removal, a telescope or slip joint may be used for the pipe sections to which the meters attach.

meter testing, meter repairing, meter reading, and meter records.

No attempt will be made in this paper to discuss each item in detail, but attention will be given to those which more directly affect the final results—that is, "total water through all service meters." This is not to imply that some of the other items may not be equally important, for each one requires special study and consideration if the best overall results are to be desired. Type of setting, for example, may not in itself appear to be significant, but often, especially in battery setups (*see* Fig. 4) and other special cases, the setting must be in accordance with definite procedures or improper registration may occur. A properly set meter will not always be the cheapest, of course, but it may eventually pay higher returns to the utility because of better registration and easier maintenance.

TABLE 2

Pumping and Registration for Master Meters, 1954

Station	Total Water Pumped—*mil gal*	Master Registration—*per cent*		
		Jan. 1954	Dec. 1954	Avg
North Street	166.043	100.31	100.8	100.55
Baxter Street	296.746	99.48	102.5	100.99
Newhall Avenue	263.032	97.09	100.8	98.94
Moreland Avenue	280.165	100.68	101.1	100.89
Total	1,005.986			

Meter Selection

In many water utilities the size of the service pipe installed has been generally used as the important determining factor in selecting the proper-sized meter for the installations. This method will not always give the best results and should be avoided in preference to a more analytical solution. The majority of Waukesha's service pipes are either ¾ in. or 1 in. in diameter. One-inch diameter copper pipe is the minimum size used for all new services, however. Accordingly, most of the meters for these services are of the ⅝-in. disc type. Occasionally a 1-in. meter or larger may be necessary if the customer requires it and if the service can deliver a sufficient quantity. A good practice is to install the smallest meter consistent with anticipated demands, without exceeding the manufacturer's rated capacities for the meter. In other words, if the maximum demand of a service is expected to reach 20 gpm, a ⅝-in. disc type of meter should be used and not a larger meter, as registration of the lower flows will not be as accurate. In this example, one can be reasonably sure that if the maximum demand is to be 20 gpm, the average rate of flow will be anywhere from 50–75 per cent smaller, although there will always be a surprising amount of flow even below the ¼-gpm rate. It is with this 10 per cent of water used at these very low rates of flow that the smallest meter proves its worth.

Many other factors enter into selecting the right meter, but for reasons of

brevity, only a few have been mentioned. As always, economic limits will also enter into the scene and a point will be reached where good registration can be obtained without undue effort or cost. More use should be made of recording meters and service flow testing data in order to better substantiate the final selections made. This feature not only gives the manager or engineer something tangible with which to work, but also offers certain public relation features that should not be overlooked.

Fig. 5. Use of Gear Train Alignment and Seating Devices

Meter Testing

To arrive at accurate data for "total water through service meters," the meters must be periodically tested. Meter testing can be divided into the following operations:

[1] testing new meters,

[2] testing a meter after removing it from service, and

[3] retesting a meter after repairs have been made.

Every new meter which is purchased should be tested to determine its accuracy at various rates of flow. Any meter that fails the required test should be rejected and returned to the manufacturer for replacement. Most new meters will prove satisfactory. If a new meter fails to meet the specified test, cleaning will usually bring it up to the standard requirements.

When a meter is brought into the shop after having been in service, it should first be cleaned well enough to remove any dirt that otherwise may find its way into the test equipment and shop. After this superficial surface cleaning, the meter should be tested, being certain that the meter is properly set in the test bench and that other recommended meter-testing procedures are followed. The test should be conducted on at least three flows, which might range from 20 gpm to 12 gpm, on one test, from 2 gpm to 1 gpm on another, and $\frac{1}{4}$ gpm or less on the lower flows. If the specifications require it, present equipment will permit testing even smaller streams with considerable ease, accuracy, and speed.

After repairs have been made on a meter, it is retested. This will indicate what type of repair work has been accomplished. The repair of the meter was done to improve its registration, and only by testing can one determine its registration. Testing is the most important part of this program because a meter which does not record close to 100 per cent of the water used is not performing its function and the utility will be the loser. As a result of this, of course, the final figures representing the "total water through all service meters" will probably be low.

Meter Repairing

Meter maintenance and repair is probably the one water works function that most directly affects the income of the utility. A good meter maintenance program produces cash results very quickly; this, however, should not be understood to imply that, simply because it is not measured in dollars and cents, a good maintenance program in other phases of water works operation is not equally important. A proper meter maintenance program has not only immediate effect but it has long range features that may be of greater value than the immediate monetary results. A maintenance program of meter repairs will not be discussed here, but it should be mentioned that the keeping of accurate records of the individual meters is extremely important. This feature is a must if any degree of success is expected.

Most water utilities have well planned and executed meter maintenance programs. Procedures and practices have been well defined, and during the past decade the art of repairing meters has come of age. History has a way of repeating itself, however; usually just when a situation gets well in hand, along comes some idea or concept that requires beginning again. This time that concept is automation. This new science will play its part in the meter repair program, and the report made by Oscar G. Goldman in 1952 (*1*) marks only the beginning. With other skilled trades paying higher wages, few young men are interested in learning the meter-repairing skills; the increased difficulty in enlisting apprentices will force management to depend more and more on mechanical, electrical, and other means of accomplishing their program. Higher accuracy and faster repairs at less cost will be mandatory.

During 1949, Waukesha's meter repair program was carefully analyzed in an effort to improve some of the old techniques and to add new ones that appeared to have merit. With the close cooperation and assistance of Francis Cunningham * (now retired) gear train alignment and seating devices were developed and tested. The tools are simple to use, and, from the experience gained, they indicate that they can do the job for which they were intended. Perhaps these tools or gages, combined with those used by the San Francisco Water Department and others, may be the beginning of new meter-repairing techniques.

Fig. 6. Use of Upper- and Lower-Alignment Devices

* Francis Cunningham, formerly salesman for the Neptune Meter Co., New York, N.Y.

Figure 5 shows how the gear train alignment and seating devices are used. These two gages are used together to determine whether or not the gear train and its control block are seated correctly. Figure 6 shows the upper- and lower-alignment devices and how they are used simultaneously to align the gear train seat if the test, as shown in Fig. 5, indicates that the clearances are not within the allowable limits.

Conclusion

The results of meter checking and repair programs can be judged in terms of the formula given at the beginning of this discussion. In 1954, Waukesha accounted for 938,589,500 gal of the 1,005,986,000 gal recorded through the master meters. It can now be shown, by simply substituting in the formula, that the percentage of water accounted for in 1954 at Waukesha was

$$\frac{938,589,500}{1,005,986,000} \times 100 + 0.32$$

or 93.26 per cent. This could only be arrived at through a whole meter program. A halfway program does not succeed.

Reference

1. GOLDMAN, OSCAR G. Testing and Repairing Small Water Meters. *Jour. AWWA*, **44**:115 (Feb. 1952).

Water Metering for Increased Revenue

Wentworth Smith

A paper presented on May 9, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Wentworth Smith, Vice-Pres., Neptune Meter Co., New York, N. Y.

THE use of water meters goes back at least to the time of ancient Rome. Then, even as now, the need for increased revenue and the desire to decrease unwarranted demand led Frontinus, the water commissioner under Emperor Nerva, to develop and install on each service an orifice type of water meter. In the process of installing orifices on the service line to each customer, Frontinus discovered the existence of some unauthorized service connections. Once these were controlled, demand was reduced, revenue was produced, and Rome's water system was able to be properly maintained and expanded.

Since those days meters have become precision instruments that measure water with remarkable accuracy. Water works administration has developed greatly since then. But the problems that were met and solved in Rome are still being met and solved today by the use of meters.

Use of Meters

The development of positive-displacement meters made possible the widespread metered sale of water. Surprisingly enough, until about 1880, the idea that the charge for water service should be based on the amount consumed was not too widely held. Experience of more than 50 years, however, has confirmed the validity of the principle that metered rates are more equitable to the individual consumer than any other method of charging for water service.

When properly used, water meters aid and protect the taxpayer by encouraging proper usage and by producing revenue. Meters thus provide the most practical means of making a water system a self-sustaining operation. In too many cases, however, the general public does not understand their importance.

Fortunately, water works operators are more enlightened. In the United States today it is estimated that 90–95 per cent of the 17,000 organized systems use meters. This does not mean that all of these communities are 100 per cent metered: metering may consist of having only a dozen meters on the town's major industries, or it may consist of universal metering, with meters installed on all services, including residential, industrial, and public buildings.

The idea of measuring water and selling it as a commodity based upon the quantity consumed has developed slowly. For years, the general philosophy was to group water service with police and fire protection, road maintenance, and schools as a necessary governmental and social service. The slowness in recognizing water service as a utility, like electricity or

gas that can be paid for on the basis of the amount used, probably resulted from the very low cost of water. At its usual price of 5–10 cents per ton delivered, the cost of water is still below that of any other commodity and even cheaper than dirt. Yet without water no community can exist.

The cost of producing and delivering water has increased steadily. More realistic rates meet this increase to some extent, but better rates have not generally been sufficient to provide for operational replacement and normal expansion costs. As a result, the effective use of metering has been found to be the most practical way of increasing water system revenue in a businesslike fashion. How metering can be and is being utilized to accomplish this purpose can be seen in the experiences of scores of communities throughout the country.

An analysis of these experiences shows that there are four major situations by which meters help increase water system revenue. They occur:

1. When towns begin metering and go from flat-rate charges to even partial metering
2. When they go from partial to universal metering (this means from coverage of 5–10 per cent commercial and industrial consumers to that of all residential customers)
3. When water utilities decide to initiate a periodic testing and repair program, and
4. When they start using metered water rates as the basis for sewage disposal charges.

There are several other situations in which the very existence of meters and their proper utilization benefits the revenue picture of a water utility. These will be discussed later.

Need for Meters

Before getting into detail on some specific examples of the ways in which meters help increase revenue, some of the other reasons for metering will be examined so as to avoid confusing them with the specifically financial benefits.

The first basic reason for metering is actually an administrative one. In order to do the best possible job in any field it is necessary to have the facts. Decisions and judgments, to be right, must be based on the best available data. In the water works industry it is generally accepted as good practice for operators to know how much water was pumped and how much arrived at destination and was actually delivered to the customers.

Having such data makes possible a comparison between water produced and water delivered. This, in turn, results in determination of the percentage of water which is not accounted for, and this percentage, if costly treatment is involved, can be very significant.

The relatively small town of Big Rapids, Mich., will serve as an example here. Shortly after the war, complete metering of the town's 1,500 services produced figures that showed the amount of water unaccounted for totaled 60–70 per cent of the water produced. Detection and repair of huge underground leaks reduced this percentage, until, 2 years ago, the percentage had dropped to as low as 6 per cent.

Another reason generally given for metering, and this one also is not based on economic principles, is that meters are the only fair way to charge for water as far as the individual consumer is concerned. This principle was

strongly advocated by the late Allen Hazen, one of the nation's most highly regarded civil engineers. As far back as the 1920s, he pointed out that the use of meters was the only way to eliminate gross inequalities and discrimination in distributing water. This may be an ethical reason or a social one, but basically it involves the principle of fair play. Metering of water sold results in the customer's paying for what he actually uses and not for what his neighbor wastes.

A third major reason given for metering is conservation. John Freeman, another of this country's highly regarded civil engineers, urged metering as the only practical method for restricting excessive waste. In fact, as long ago as 1900, he advised the use of meters to reduce the waste of water in New York City. Conservation, however, or the saving of water, would seem to be an economic factor. If we accept the growing trend in the water works industry to recognize water as an essential economic commodity, the saving of water or the reduction of waste should be counted as an economic gain. For the purpose of this discussion, therefore, conservation of water is most definitely an economic asset. No matter how staunchly one upholds the validity of the claim that "water should be free" and that "it is a gift of God," there are some costs that must be taken into consideration. It takes money to gather, store, filter, pump, and distribute water to the consumer's home. Therefore, conservation and the reduction of waste must be included in the total economic picture of a water system.

While cutting waste does not increase revenue, any tangible conservation of water does result in an actual reduction of expense in both production and distribution. Reducing expenses helps increase the profit side of a water utility's balance sheet at the end of the year. Water conservation therefore becomes a tangible economic asset.

Partial Metering

Let us now consider the first type of situation in which metering helps increase revenue—that is, when a town which uses no meters at all decides to begin metering.

Shortages and increased demand, or just good water works practice, lead to the start of metering and the abandonment of flat rate charges. When this is done the first step is generally in the industrial and commercial fields. In most urban communities, whether they are large or small, initiation of metering has been an important step which almost immediately has resulted in tangible benefits.

Statistics of the water works industry, which indicate that 90–95 per cent of American communities have meters, refer to this widespread acceptance of measuring the water delivered to commercial and industrial consumers. Towns may be listed in this category, even if they have only a dozen meters, but all of these metered premises will, in all likelihood, be industrial installations. This type of partial metering may gradually be extended to include 10–30 per cent or even more of the residential installations in a city, and tangible benefits in increased revenue, whether direct or indirect, are clearly evident.

In speaking of indirect benefits, it is the reduction in waste and resulting drop in demand of water delivered that is meant. In each case, the costs are

related to the individual community where the charges for treatment, distribution, and other costs are based on local conditions.

Statistics and types of data available from various communities differ materially, but the pattern of benefits derived from metering is quite uniform. When Walla Walla, Wash., was half metered, for instance, the demand was reduced 20 per cent.

In Plattsburgh, N.Y., in 1953 when the town was half metered, daily consumption had dropped 1.2 mgd as compared to the demand 5 years before when the flat rate was in effect. This drop from 3.8 mgd to 2.6 mgd was recorded despite a normal population increase over the 5-year period.

Another approach, and a more direct one in terms of revenue, is seen in the much larger city of Chicago. Data from Chicago point up this pattern very tangibly. Some years ago, when the city was only 23 per cent metered, the income from metered consumers was almost three times this percentage—that is, although the city was only 23 per cent metered, 68 per cent of the income of the water supply system came from metered users. Many of these meters were on industrial services, of course, but this only serves to point up the importance of metering large-volume consumers.

The importance of metering industrial and commercial users is also reflected in reports of studies made by operators on an altogether different problem—that of getting the right size and type of meter on each installation in order to obtain the maximum revenue to which the water utility is entitled. These studies have included experimentation with battery settings and sometimes reduction of the size of the meter from that originally specified, probably by someone other than a water works operator.

One such study, made in Grand Rapids, Mich., for instance, covered only twenty industrial and commercial installations. Yet changes which followed the review of types and sizes of meters in use resulted in a net increase of $21,277 above the total income derived from these twenty services the year before.

This example is mentioned merely as an instance of the substantial amount of revenue coming to this water system from only twenty industrial meter installations. The $21,000 increase, resulting from proper selection of meters is just so much added dividend.

Universal Metering

The best tangible proof of how meters increase revenue is to be seen in the experience of those towns that are 100 per cent metered. The statistics from any metered community in the United States, regardless of population or location, show that meters help increase revenue both directly and indirectly.

Universal metering, by recording the output of every water service connection on individual meters, makes possible the selling of water by accurate measurement. Besides the proved advantage of making the consumer conscious of any undue wasting of water on his premises, universal metering makes possible the application of scientific cost-accounting principles to water works administration.

The recorded experience of more than 50 years of metering is filled with statistics on the actual reduction of water demand caused by elimination of waste. The literature of the industry is filled with reports of percentages,

per capita demands, daily, monthly, and yearly reductions in output of water when communities are 100 per cent metered. The economic advantage of such reduction is clearly one of the indirect benefits that results in an increase of revenue on the yearly balance sheet.

A few examples of actual cash increases will illustrate the above point. The classic example is that of Milan, Tenn., a town of about 5,000 population. Metering reduced water consumption 50 per cent. Power cost for pumping was reduced 25 per cent in dollars and cents, equal to about $100 per month in net saving. The average increase in gross revenue was approximately 45 per cent.

Gross revenues rose from $24,439 for the year ending June 1945 to $36,081 for the year ending June 1948. This represented an increase of 47.6 per cent. During this period there was no great increase in customers, but there was a reduction of power costs from $5,335 to $3,566, or a reduction of 33.4 per cent.

The experience of Milan is not unique. Tucson, Ariz., for instance, during a 10-year period of experience with metering, reported an increase in revenue of $371,900, while pumpage dropped 26.8 per cent. During this same period the total saving in power cost was $174,100.

Another example is Cheyenne, Wyo. The revenue from the sale of water in 1943, 10 years after meters were installed, was $248,000—almost double the $128,000 of 1933 which was the last year of flat rates. In addition, it is interesting to note that in 10 years of metering, although revenues doubled, water consumption was not as high as it had been with flat rates. The number of accounts had increased substantially.

A totally different type of data comes from Brownsville, Ore. Here, not only did the water department gain a net increase in revenue in 1954 as a result of metering, but the customers did also. After metering was completed in this community, rates were reduced so that customers were charged $2,614 less than for the year before meters were installed. This savings was credited to elimination of waste through repairs to leaky plumbing. The water department, on the other hand, reported a net gain of $917 for the first year of metering because of a substantial saving in the cost of power.

In Texas, as in most of the southwest and the west, water conservation is vital. At the same time, revenue is an important consideration. A final example of how universal metering helps increase revenue is seen in the experience at Columbus, Tex., a town of about 5,000 population. These figures are all from the last 3 months of 1955. In October, Columbus pumped 44.144 mil gal when the flat rate was in effect and while installation of meters was being completed. In November, with metered rates in effect, pumpage dropped to 18.936 mil gal. In other words, pumpage dropped 56 per cent. During October, with flat rates, the power bill for pumping was $759. In November the pumping costs had dropped to $356. But that is not the whole story.

The metered rates turned the water works from a deficit operation into a self-supporting one. Flat rates during October brought an income of $2,302. In November the metered rates brought the water department $2,826

and in December the revenue had climbed to $3,140.

These examples of the benefits of universal metering speak for themselves.

Testing and Repair

Like any other mechanical device, water meters wear with time and lose their peak efficiency. The time span during which meters accurately record all water varies considerably depending on local conditions.

Methods of testing and repairing meters have been fairly standardized so that training personnel to do a proficient job is within the reach of most operators. That it is worthwhile to invest the time and money in a periodic maintenance program has been fairly well proved. Results of maintenance programs in small towns and large, in all parts of the country, indicate that unaccounted-for water slipping through worn meters is depriving the water systems of income rightfully earned.

The economic advantages of meter maintenance can be seen from a few examples. The town of Cortland, N.Y., with 4,500 services, started a meter survey in 1950. Four years later, after 50 per cent of the meters had been tested and about 25 per cent had been repaired, the results were as follows: water pumped had dropped from 972 mil gal in 1950 to 807 mil gal in 1953; cost of power for pumping had dropped from $9,018 to $6,505; revenue had risen from $68,957 to $78,071.

Green Bay, Wisc., launched a meter survey when it found that it could account for only 64.54 per cent of the water produced and when revenue totalled $264,877. Four years later, when the program had been completed, the accounted for water had climbed to 81.44 per cent and revenue had risen to $301,245. Figures in Green Bay showed that almost the same amount of water was pumped before and after the meter survey, with the same rates in effect. Revenue received by the department, however, was $36,367 greater in the year the survey was completed.

In another Wisconsin town, Kenosha, a similar survey which lasted over a 7-year period show these results: 94.5 per cent, rather than 69.3 per cent, of produced water was accounted for; although total pumpage was the same in the years before and after the survey, the revenue was $22,747 greater after the maintenance program had been completed.

In Brookline, Mass., a town of 50,000 population, a 7-year control program resulted in an increase of revenue from $286,000 to $406,000, or a gain of 42 per cent.

In Greenville, Tex., a town of 17,500, when the meter maintenance program was one third completed last summer, billings had already shown an increase of 35 per cent, adding some $10,000 in revenue.

One of the factors which resulted in the winning of an "All-American City" designation for Bloomington, Ill., last year was the increase of $50,000 a year in revenue following a meter-testing and repair program.

One final example of how meter maintenance cuts waste and increases revenue is seen in the experience of Hollywood, Fla. In 1953 total pumpage was 996 mil gal. In 1954 pumpage had dropped to 923 mil gal. The revenue picture, of course, was the reverse. Revenue went from $355,500 to $430,128, which was an increase of $74,627.

The whole process of testing and repairing meters generally results in bringing meters back to top efficiency, particularly where the small flows have not been registered. As small flows make up a large percentage of the average consumer's demand, the importance of meter maintenance to revenue can be seen.

Sewage Disposal Charges

The trend of using metered-water service as a basis for setting up sewage disposal charges results from the recognition that most water distributed through a city's water system eventually reaches the sewer system. Instead of providing sewage disposal as another governmental service, the basing of sewer charges on metered-water use is considered to be the most equitable system of levying such charges.

Sewer charges based on metered-water readings are simple enough to understand, easy to apply, and fair enough to be acceptable to the people in each community. Charges can be expressed as a percentage of the water bill or as rates based on water consumption. In any event, sewer charges are a valid and lucrative source of revenue for financing the construction and operation of sanitary sewer systems and sewage treatment plants. The trend toward basing charges on metered-water use is being speeded up by the goal of putting sewage disposal on a self-sustaining basis. The use of meters contributes to the increase in revenue.

A typical instance is the experience of Boulder, Colo., which, in January 1954, changed from a flat rate to a proportional sewer service charge based on the amount of water used during the first quarter of each year. The new schedule raised the average residential rate from the previous $2.14 a year to $5.47 a year. For all customers, including business places, the average cost went from $3.04 to $7.37. This raised the city's revenue for sewer maintenance from $16,300 in 1953 to approximately $38,000 in 1954.

With that type of increase, the conclusion may be made that the use of meters helps substantially to increase revenue, in addition to encouraging the elimination of water waste and furnishing the most equitable manner of charging for the sale of water.

There are still other ways in which meters affect revenue, and one final situation should be mentioned. Quite often, when revenue bonds must be sold to provide funds for expansion of facilities, a substantial savings may result through lower interest charges when the community is metered. This type of saving is just one of the many other instances where metering helps increase revenue.

Summary

Meters make a noticeable contribution to the efficiency and financial benefit of a water system in four sets of circumstances: when a town goes from flat rates to partial metering; when it goes from partial to universal metering; when it adopts a periodic maintenance policy; and when a town uses water meters to determine sewer charges.

It may be concluded, therefore, that water meters, properly maintained, can help assure both that the consumer does not pay for the water his neighbor wastes and that the water system gets paid for all the water it distributes.

New Algicides

As a result of the presentation and publication of the paper, "Evaluation of New Algicides for Water Supply Purposes," by C. Mervin Palmer (September 1956 JOURNAL, p. 1133), the AWWA has received a number of inquiries on the sources from which the various chemicals can be obtained. To answer these inquiries, Mr. Palmer has prepared a list of the chemicals, their trade names, and manufacturers. Its publication here is intended for the convenience of those interested and **does not signify approval by the American Water Works Association of the algicides listed.** Before any such chemical is applied to water used for a public supply, approval should be obtained from the state health department.

Algicide	Type	Trade Name	Manufacturer*
Actidione	Antibiotic	Acti Dione	Upjohn Co. Kalamazoo, Mich.
Dodecylacetamido dimethylbenzyl ammonium compound	Quarternary ammonium compound	Nopocide-K 100%	Nopco Chem. Co. Harrison, N.J.
Rosin amine D sulfate	Rosin amine	RADS	Agricultural Chemicals Div. Naval Stores Dept. Hercules Powder Co. Wilmington, Del.
Rosin amine D acetate	Rosin amine	Delrad RADA Algicide D	
2,3-dichloronaphthoquinone	Quinone	Phygon-XL	Naugatuck Chem. Div. United States Rubber Co. Naugatuck, Conn.
Colloidal or activated silver	Activated silver	Movidyn Algaedyn	United States Movidyn Corp. Chicago, Ill.
3-(p-chlorophenol)-1,1-dimethylurea	Urea compound	CMU	Grasselli Chemicals Dept. E. I. duPont de Nemours & Co. Wilmington, Del.
Sodium pentachlorophenate	Chlorophenate	Santobrite	Organic Chem. Div. Monsanto Chem. Co. St. Louis, Mo.
Streptomycin sulfate	Antibiotic	Streptomycin	Charles Pfizer & Co. New York, N.Y.
Neomycin	Antibiotic	Viocin	
Terramycin amphoteric Terramycin hydrochloride	Antibiotic	Terramycin	
Zinc dimethyl dithiocarbamate	Organic zinc	Zineb Dithane Z-78	Rohm & Haas Co. Philadelphia, Pa.
Ferric dimethyl dithiocarbamate	Organiz zinc	Fermate	Grasselli Chemicals Dept. E. I. duPont de Nemours & Co. Wilmington, Del.
Copper-citrate combination	Copper compound	Cuprose	National Aluminate Corp. Chicago, Ill.

* Manufacturers given are not necessarily the only manufacturers of the product.

Galvanic Corrosion in Water Meters

Herbert F. Barrett

A paper presented on May 10, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Herbert F. Barrett, Sales Mgr., Buffalo Meter Co., Buffalo, N.Y.

GALVANIC corrosion of water meters has cost the water works of the United States many millions of dollars since the use of water meters on a large scale started about 60–70 years ago. The loss comes not only from damage to meters, but to an even greater extent from revenues lost through stoppage of registration. Meter manufacturers have sought to build meters which would minimize the corrosive effect of the water. Much progress has been achieved; but, to the author's knowledge, there has been little public discussion of this subject, nor have the principles been gathered together in a single statement having particular reference to water meters.

The facts herein presented come from three main sources. The first comprises the tests and studies made by the author and others for the Buffalo Meter Company. Second are the studies on corrosion in water meters done by the Engineering Research Institute of the University of Michigan. The first of these was a relatively simple study done in 1923 for the city of Kalamazoo, Mich., by William P. Wood (*1*). In 1954 Wood made a much more detailed laboratory study of galvanic corrosion for the Buffalo Meter Company (*2*). This study investigated many phases of galvanic reactions among various meter parts and meter materials, under a range of water conditions. The third source includes the extensive corrosion investigations performed by the International Nickel Company, as well as conferences and correspondence with representatives of that firm. These sources have provided a very extensive background against which other tests could be double checked; they also furnished statements of the practical application of the chemical principles involved.

The chemistry of water is incredibly complex. The mineral content of water, and hence its corrosive effect, varies from well to well, from lake to river, from town to town. In many places it also varies according to the season; and the properties of a water in summer may be very different from those of water coming from the same source in winter.

The nature of the treatment given to a water after it has entered the system also changes its effect upon metals. Treatment or storage may expose the water to air, so that if it was not saturated with oxygen originally, it has been by the time the treatment is finished. This may accelerate the corrosive tendencies of the water, and the compounds added or subtracted during treatment may further change the properties of the original raw water.

Laboratory Test Limitations

The problem is complicated by the fact that the corrosiveness of a water is difficult to analyze. A sample is drawn from a system and sent to a laboratory for analysis, but the properties of the sample may have changed before it reaches the laboratory. The sample may have picked up some silica from the glass bottle in which it was shipped, and this would tend to make the sample less corrosive than the original water. It will certainly have become saturated with oxygen, if it was not originally so. Beyond this, the test of that sample in a laboratory will lack the effect of flowing water, about which more will be said later.

Water analyses are also incomplete. It is not possible to determine exactly which positive atoms of minerals in the water are combined with which negative atoms. In fact, water is such a solvent that the positive and negative atoms of a dissolved compound are held together only very loosely—they will separate about 80 times as easily in water as in air (*3*). This means that a mineral compound will break down very easily in water, with the result that the negative atoms of the compound may combine with the positive atoms of a metal in contact with the water to form some new compound that uses up part of the metal. This is one reason why water containing only a relatively small amount of mineral may cause a surprising amount of corrosion in a supposedly corrosion-resistant metal.

Tests of the corrosiveness of water made in a laboratory from water samples are, therefore, of very little value. The sample in a laboratory is no longer fully representative of the water in the main. (The author does not refer to the various tests made for health purposes, but only to tests of corrosiveness.)

A portion of the 1954 University of Michigan study had to be carried on with very large samples. These results, however, were not depended upon for absolute values, but only for the relative effects of several different waters and the relative amounts of electric current produced in galvanic couples of meter metals in those waters.

The velocity of water flow also has its effect upon the corrosion of meter metals exposed to water. It is well known that an increase in the speed of flow of a current of water increases any corrosive tendency because more fresh water is brought in contact with the metal, and there is a greater likelihood that the byproducts of corrosion will be washed off the surface of the metal. In an article by Lee Streicher on the effects of water quality on various metals (*4*), he incorporated a chart of the effects of water velocity on the corrosion rate of metals based upon tests in treated water of the Los Angeles Metropolitan Water District. Although he did not make any tests on bronze of the 85-5-5-5 composition generally used in water meters, he did test a yellow-brass sample which was presumably about 70 per cent copper and 30 per cent zinc. Inspection of Streicher's chart shows that at a velocity of 6 fps the corrosion rate on the yellow brass was about 20 mg per square decimeter per day (mdd), and at 12 fps, at least 30 mdd. Twelve feet per second is considered a high velocity for flowing water; but in a $\frac{5}{8}$-in. meter, the velocity through the ports at the rated limit capacity of 20 gpm is about 29 fps. Even through the larger area of a measuring chamber in an average-size meter the velocity at 20 gpm is about 7.7 fps or at 10 gpm, 3.85 fps.

Whatever corrosive tendency exists in the water will, therefore, naturally be accelerated by the velocities prevailing as the water flows through a meter. A few cities rely extensively on the use of full ¾-in. meters instead of the usual ⅝-in. size to get better meter performance. Considering the velocity effect, however, it is questionable whether the longer life of a larger meter is the result of less mechanical wear from fewer disc movements and gear rotations, or whether it is the result of less velocity-induced corrosion. A ¾-in. meter should have one-half the disc nutations of a ⅝-in. meter, so the velocity through the measuring chamber would be cut in half and the velocity-corrosion effect would probably be reduced very substantially.

The author believes the limitations on the life of a water meter are caused by corrosion and abrasion and the effect of mineral deposits and of velocity rather than by the inherent effect of the movement of the metal parts in pure water. Accelerated tests of meters have been made under favorable water conditions, the meters being run for quantities equivalent to 100 years of average family use, after which the meters still passed the accuracy test for new meters. This is never achieved in service, primarily because of galvanic corrosion; but under corrosive conditions this may also be substantially affected by velocity.

Under difficult water conditions, investigation should be made to determine whether longer meter life may be obtained by the use of larger meters to reduce the velocity-corrosion effect.

Definition of Galvanic Corrosion

When considering galvanic corrosion in water meters, it is first necessary to define the term "galvanic corrosion." International Nickel Company has defined it (*5*) as follows:

> Galvanic corrosion is an accelerated electrochemical corrosion, produced when one metal is in electrical contact with a different metal, both being in the same corroding medium or electrolyte. Corrosion of this type results usually in a higher rate of solution of the less noble metal, and protection of the more noble metal. During the corrosion process, an electric current is generated by the two metals in contact, the magnitude of this current being equivalent to the acceleration of the corrosion of the more vulnerable metal beyond its normal extent.

The same company also publishes a table of galvanic series of metals and alloys. Based upon tests of galvanic-couple reactions, this list is slightly different from the more usual "electromotive series" used for determining electrochemical corrosive reactions. In the galvanic series, the metals generally used in meters appear in the following order, starting from the protected or cathodic or "most noble" end of the series; [1] passive stainless steel; [2] Monel; [3] copper-nickel alloys; [4] bronzes; [5] brasses; [6] tin; [7] active stainless steel; [8] cast iron; [9] zinc. Any metal toward the beginning of this list is protected by any metal further along in the list, the protection being accomplished by the sacrifice of the corroded or anodic or "less noble" metal. Applying to water meters the principles of the galvanic series of metals as they are actually seen to work out in practice, many interesting facts are observed.

Common Galvanic Couples

Galvanic Couple No. 1. The basic metal of meters built to resist water corrosion is usually a bronze alloy of about 85 per cent copper, 5 per cent

zinc, 5 per cent tin, and 5 per cent lead (85-5-5-5). This has generally good corrosion resistance and is moderate in cost. The standard of corrosion reference is therefore the all-bronze meter cast from the same alloy throughout. In practice this cannot be achieved, because some small parts, such as the diaphragm, shafts, and screws, must be made from rods or sheets. The chemical and physical properties of rod or sheet metals are not exactly identical with those of the cast parts; but if Grade A phosphor bronze containing 5 per cent tin is used, the properties are so close to those of the castings that galvanic reaction is minimized. This, plus the experience of meters in service, leads to the following conclusion: *Under average water conditions, galvanic corrosion will be minimized if meters are composed of metals as much alike as possible, although sometimes dissimilar metals are deliberately used to produce a galvanic couple to protect one at the expense of the other.*

Galvanic Couple No. 2. At the opposite extreme, the greatest galvanic reaction occurs within a meter having bronze works and all or part of the casing made of cast iron. This situation occurs in frost bottom meters, in meters of large sizes, in one brand which invariably uses an iron casing, and in the wartime meters built by several companies. The couple of bronze and cast iron produces the greatest voltage potential and current flow of any couple that may be found in meters. The University of Michigan tests showed a voltage potential averaging approximately 0.4 v and current flow of 1–5 ma, which are much larger values than were found under comparable conditions with any other combinations of metals. The bronze is, of course, protected at the expense of the iron.

The Streicher flowing-water test (*4*) on a couple consisting of copper and galvanized iron, taking place over a period of about 8 months, showed negligible corrosion of the copper, but substantial penetration of the galvanized iron, when tested in treated waters. When the couple was exposed to untreated well water, no pitting of the galvanized iron was observed, and only a moderate amount of weight loss, distributed fairly evenly between the copper and the galvanized iron, was noted. When black iron and copper were coupled together in an identical test, the results were similar, but the corrosion of the black iron was somewhat greater.

The untreated well water, in which the iron-copper couple stood up best, contained very little dissolved oxygen, but did contain a substantial amount of bicarbonate hardness. It differed from the same water after treatment chiefly in the fact that the water became partially saturated with oxygen during treatment, which would, of course, accelerate any corrosive tendencies. This coincides with observations over many years that meters with casings made entirely or partly of iron give best results in well water with a pH on the alkaline side, with a fair amount of bicarbonates present, and with very little dissolved oxygen. Towns which formerly used meters having such iron parts with excellent success find that corrosion of the iron may be greatly increased after the installation of a treatment plant. This also explains why many of the wartime iron casing meters made by various companies had short lifespans. They were installed in large cities having treated water or surface supply which

was saturated with oxygen, and where the properties of the water were not suitable for a bronze-to-iron galvanic couple, especially when the iron was not protected by galvanizing. Another factor, certainly, was the effect of velocity rates through meters, as mentioned earlier. This would help account for the fact that iron casing meters in 3–12-in. sizes are frequently used successfully in water systems where such construction would not be satisfactory for small meters operating under greater velocities.

Many frost bottom meters contain some means of minimizing the galvanic couple between the iron frost bottom and the bronze chamber. This may be done by the use of a plastic or brass liner, or by galvanizing or enameling the frost bottom. In the 1954 Michigan tests, the current flow between the bronze chamber and three types of frost bottoms was tested: one type had a liner of polyvinyl chloride plastic; the second was galvanized and then painted with asphalt base paint; and the third was merely galvanized. In water of moderate pH, all three were equal in galvanic reaction; but in water with very high pH, the current flow was least with the polyvinyl chloride lining.

When a brass liner is used in a frost bottom, the liner is protected by contact with the iron bottom, whether the bottom is galvanized, enameled, or painted; but there is a separate galvanic cell between the brass liner and the bronze chamber. The liner is anodic to the chamber, and therefore is corroded and dezincified, especially because the liner is brass containing up to 30 per cent zinc. Having an initial thickness of only about 0.020 in., the liner does not last long if the water creates much current flow between the brass and the bronze. Once holes develop in the liner, the galvanic couple is then between the bronze chamber and the iron bottom.

The problem of any bronze-to-iron couple is further complicated by the fact that after the surface iron goes into solution, a film of graphite from the cast iron may be left exposed. Graphite is cathodic to bronze, so the galvanic couple is then reversed; the bronze is corroded to protect the graphite and, incidentally, the iron which is beneath it.

Conclusions are very difficult to draw from this series of observations, as they must be determined by local conditions. One limited conclusion, however, is warranted: *If water is corrosive, some protection for iron frost bottoms, other than brass liners, should be used, as the chamber-liner couple may corrode the liner, causing holes which permit the unprotected iron to be strongly attacked.*

Galvanic Couple No. 3. The third couple is that of the bronze casing and nickel-bronze chamber, which is ordinary bronze with about 20 per cent nickel added. The solution potential and the current flow of this couple are in the same direction as that of the iron casing and bronze works, except that the difference in potential is rather small. The nickel-bronze chamber would tend to be protected at the expense of the casing. The nickel-bronze chamber must be combined with nickel alloy diaphragm and disc pin (also shafts and screws where exposed to the water), or these small parts would be very rapidly corroded. The combination is probably best in acid water, or in water containing chlorides, such as found in some seacoast regions. The nickel-bronze chamber is not a cure-all for corrosive conditions. There is hardly enough experience yet to

indicate just where it should be used, except that it is tried most extensively where severe pitting and formation of holes in bronze chambers occur. A limited conclusion may be stated on this point, as follows: *Nickel-bronze chambers should be used only where experimental tests show them to be specifically helpful, but never in meters having iron frost bottoms.*

Galvanic Couple No. 4. The next couple to consider is that of bronze measuring chamber against brass case, the case containing probably 10–15 per cent zinc. Here also the galvanic couple is in the same direction as iron case and bronze chamber, or bronze case and nickel-bronze chamber, but the reaction is very mild. Some dezincification of the case would usually occur, which would tend to protect the chamber. The casing is relatively thick and heavy, however, and therefore is not seriously affected unless there is a strong tendency toward dezincification, which would eventually create holes. Most meter companies do not use this particular couple.

Galvanic Couple No. 5. This couple involves tin plating of bronze castings. Tin is very slightly anodic to bronze, and thus protects the bronze; however tin is not very far from bronze in the galvanic series. In a meter, the tin-plated area would usually be large in ratio to the unplated area, so the corrosive effect on the tin would be mild. This construction has the advantage of preventing the formation of green copper salts on the rough cast surfaces, tin salts being usually whitish and inconspicuous.

Galvanic Couple No. 6. Another couple is that found in a meter having bronze casing and works, with small parts, such as the diaphragm and shafts, of Monel. In theory, Monel is slightly cathodic to, and hence protected by, bronze. The University of Michigan tests on actual combinations of Monel shafts and bronze gears in various waters showed a slight voltage potential in favor of the bronze at the start of the test, but this had almost disappeared at the end of 24 hr. Considering the polarizing tendency of Monel, it is probable that a lengthy test would have shown a condition of almost complete balance in potential after a longer time. Throughout the tests, the current flow between the Monel and bronze was zero in water of ordinary pH and conductivity. Galvanic corrosion is the result of total current flow rather than of the solution potential, and as there was no current flow there was, for practical purposes, a galvanic balance between the Monel and bronze. The waters used in this particular group of tests were all low in chlorides, so it is possible that some different results would be obtained in the presence of chlorides or sulfides, especially if combined with acidity. For average water conditions, however, these figures raise the question of whether there is any appreciable value in making small parts of Monel. With no current flow, there would be no protection either way.

Comparison of the Monel-to-bronze couple and the bronze-to-nickel-bronze couple do not seem to agree. There was a substantial potential and current flow in the bronze-to-nickel-bronze couple that was greater at the end of 24 hr than at the beginning, whereas the trifling differential in the opposite direction between the Monel and bronze in their couple disappeared almost entirely in 24 hr. The difference may be a result of the fact that the Monel parts were drawn or rolled rather than cast; or perhaps Monel has

a greater polarizing capacity than the sand-cast nickel bronze. LaQue and Cox (*6*) state that metals and alloys divide themselves into groups in a galvanic series and that "materials may change places within any group depending on the incidental conditions of exposure." Such incidental conditions on the surface of metals might easily account for the observed behavior of the Monel and the nickel bronze in contact with 85-5-5-5 bronze. In any event, the Monel-bronze couple is uncertain in value for galvanic-corrosion purposes.

Galvanic Couple No. 7. Another variation is that of a bronze casing and works, with small parts, such as diaphragm, shafts, and screws, made of stainless steel, usually Type 304. If the stainless steel is passivated, it is then cathodic to, or protected by, Monel, and more so by bronze. But if in an active form, it is then anodic to, and corroded by, bronze. Active stainless steel is very close and similar to cast iron in the galvanic series. Presumably any stainless-steel parts would be passivated by the manufacturer before assembly, but any rubbing action on the parts could remove the passivated surface. The same effect would be produced by scratches, which might be caused by abrasive foreign matter in the water or by scraping, cleaning, or sandblasting in a repair shop. Stainless steel is also not very resistant to chlorides and can definitely be corroded by water containing any chlorine compound. Stainless-steel parts are likely to be used in a meter as a cheap substitute for Monel, as the price per pound in rods or sheets is about one-half that of Monel. The dangers resulting from the possible presence of chlorides, however, plus the near certainty that passivation will be removed from some surfaces warrant the following conclusion: *For small submerged meter parts, stainless steel will accomplish nothing that Monel will not do better and with less chance of trouble. Stainless steel must also be avoided in water containing chlorides.*

Galvanic Couple No. 8. This involves the effect of the use of pinion rods with drawn teeth, or milled from drawn rod, for pinions in gear trains exposed to the water. Laboratory tests plus observations in practice have shown that much of the difficulty which has in some places been charged to the use of open gear trains is actually the result of the use of meters having pinions made of drawn rod instead of cast rod. Stresses in the crystalline structure of the drawn rod as a result of the cold drawing can produce very peculiar effects. *Open gear trains should have pinions made from cast rod with milled teeth.*

Galvanic Couple No. 9. An experimental couple involves the coating of meter parts with molybdenum disulfide. The purpose of this relatively new idea is to reduce the galvanic potential by insulation. Tests show that this is not particularly effective. The potential and current flow are not greatly reduced below those which would occur without the coating. The coating is also claimed to have a certain slipperiness, which might reduce friction of the disc against the chamber, thus improving slow-flow accuracy. The author, however, is not aware of any tests of this factor.

Galvanic Couple No. 10. An important and peculiar couple involves the effect of moisture and temperature on meters in storage. Water works operators and manufacturers have sometimes been dismayed to find a black deposit on the inside of bronze meter

parts when the meters have not been out of the original shipping boxes. Frequently, the blame for this has been placed on the formation of some sulfur compounds, but this is usually not correct. The deposit is usually cupric oxide, caused by combination of copper with hydroxyl ions of alkaline water remaining in the meter, and probably accelerated by exposure to warmth. The black cupric oxide does not represent any defect in the meter, and probably no lack of quality in the materials, and would not interfere with the operation of the meter in service.

It is possible that another kind of black deposit could be caused on measuring chambers if aluminum impurities were present in the chamber metal, but this is very unlikely.

Galvanic Couple No. 11. The last kind of galvanic couple results from lack of quality control at some point. It is believed that all meter manufacturers are taking care to control quality, and this is highly necessary. Bronze castings made from impure metal containing traces of aluminum may corrode rapidly. If a factory or repair shop cleans castings in acid, it may be difficult to remove all traces of acid from the pores of the metal, resulting in the formation of small acid galvanic cells and severe spotty corrosion. Meter parts have been observed where pits of corrosion could not be accounted for otherwise.

The entire subject of galvanic corrosion is extremely complex. Why not, then, make meters of nonmetallic materials such as plastics? Elaborate tests have been made, but the trouble with such materials is either lack of dimensional stability, or costs even higher than those of metals, combined with limited strength. Copper alloys are still the most satisfactory material for meter manufacture.

It is hoped these observations will prove useful in minimizing the problems of galvanic corrosion, for anyone who applies them carefully.

References

1. Wood, W. P. Investigation of Corrosion in Water Meters. Dept. of Eng. Research, Univ. of Michigan, Ann Arbor, Mich. (1923).
2. Wood, W. P. Galvanic Corrosion in Water Meters. Prepared privately by Eng. Research Inst., Univ. of Michigan, Ann Arbor, Mich., for Buffalo Meter Co., Buffalo, N.Y.
3. *Inco (International Nickel Co.) Corrosion Reporter.* p. 2 (Mar. 1948).
4. Streicher, Lee. Effects of Water Quality on Various Metals. *Jour. AWWA,* **48**:219 (Mar. 1956).
5. Corrosion Processes, Factors and Testing. Development & Research Div., International Nickel Co., New York (1951).
6. LaQue, F. L. & Cox, G. L. Some Observations of the Potentials of Metals and Alloys in Sea Water. *Proc. ASTM,* **40**:670 (1940).

Service Line and Meter Requirements of Domestic Water-connected Devices

James G. Carns Jr.

A paper presented on May 10, 1956, at the Diamond Jubilee Conference by James G. Carns Jr., Meter Engr., American Water Works Service Co., Philadelphia, Pa.

AS a result of prolonged droughts, recurrent water shortages, and the rapid increase in water use during the past 5–10 years, widespread attention is being given to practices of water use and consumption in the United States. This study is limited to only one phase of the larger general problem—the need to reevaluate current practices of sizing service lines and meter installations. Although this problem may, at first glance, seem to be secondary to the need for augmenting supply sources, pumping and treatment plants, and distribution pipelines, nevertheless, in view of the demand, either actual or potential, being placed on service lines and fittings, it seems only prudent to make every effort to insure that present installations will provide satisfactory service and not become obsolete within a short time. A chain is only as strong as its weakest link; and it certainly is no consolation to a customer that all the water he requires is in the street main, if he cannot obtain it in the house because of an inadequate service connection or meter size. The significance of the problem becomes still more apparent when it is considered that the investment of a water utility in service lines and meters represents an average of 15–20 per cent of total plant investment.

Past increases in the use of water in the home have not caused any compelling problem because of the wide diversity of use of ordinary fixtures. Numerous studies have been made of maximum rates of water use in the average home, and demand rates of 6–8 gpm are commonly accepted as average. This range represents normal consumption with any two of the following fixtures in use at the same time: kitchen sink (4 gpm); laundry tub (5 gpm); bathtub (4 gpm); shower (3 gpm); tank toilet (4 gpm); washbasin (3 gpm); lawn sprinkler (5 gpm). These are average figures and vary, of course, in actual practice. It will be noted that if all these fixtures were operated simultaneously, the total flow required would be 28 gpm. If the use of the shower is deducted (as a duplication of the bathtub), the total flow is 25 gpm. It is understood, of course, that services and meters with sufficient capacity for simultaneous use of all fixtures are not installed, as experience has shown that such a situation seldom, if ever, occurs in the average home. The safety factor inherent in this diversification of use is rapidly decreasing because of

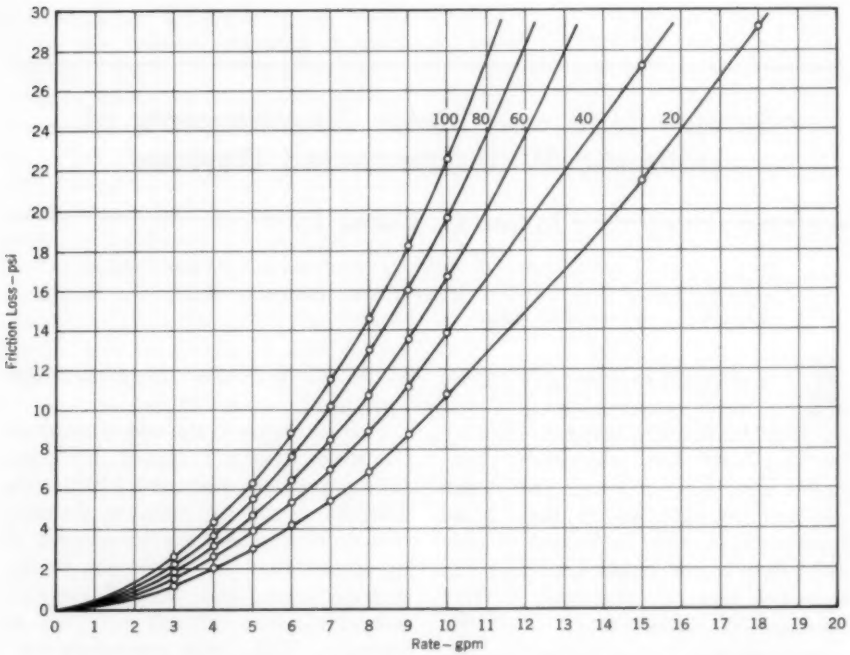


Fig. 1. Computed Friction Losses, ¾-in. Copper Service With ⅝-in. Meter

Numbers identifying curves indicate length of service, in feet.

TABLE 1

Computed Friction Losses for ¾-in. Copper Services With ⅝-in. Meter

Rate *gpm*	Service Length—*ft*				
	20	40	60	80	100
	Computed Friction Loss—*psi*				
1	0.19	0.24	0.30	0.35	0.40
2	0.55	0.72	0.89	1.06	1.23
3	1.08	1.43	1.78	2.13	2.48
4	2.03	2.61	3.19	3.77	4.35
5	3.02	3.86	4.70	5.54	6.38
6	4.06	5.22	6.38	7.54	8.70
7	5.42	6.98	8.54	10.10	11.66
8	6.82	8.72	10.62	12.52	14.42
9	8.64	11.04	13.44	15.84	18.24
10	10.73	13.73	16.73	19.73	22.73
15	21.41	27.21	33.01	38.81	44.61
20	35.61	45.01	54.41	63.81	73.21

the introduction of new types of automatic water-connected facilities. These automatic facilities cause more outlets to be in use at one time and a number of them use water at higher rates of flow than ordinary fixtures. Together, these two factors make it necessary to reconsider whether it is time now to install larger services for domestic customers.

design engineers of appliance manufacturers were not very familiar with the operating conditions of a water utility; as a consequence, it has been necessary to lengthen the time cycle of automatic washers so that they may perform properly where low pressures exist. It is not uncommon for a home to have a flow rate of no more than 4–5 gpm, at about 20 psi, with no other fixtures

TABLE 2

Computed Friction Losses for ¾-in. Service Components *

Rate gpm	Fittings and Meter					Pipe Length—ft				
	¾-in. Corporation†	¾-in. Curb Stop‡	¾-in. Globe Valve§	¾-in. Disc Meter‖	Total Fittings & Meter	20	40	60	80	100
	Computed Friction Loss—psi									
1	0.015	0.011	0.060	0.05	0.14	0.052	0.104	0.156	0.208	0.26
2	0.050	0.034	0.195	0.1	0.38	0.17	0.34	0.51	0.68	0.85
3	0.103	0.071	0.301	0.25	0.73	0.35	0.70	1.05	1.40	1.75
4	0.170	0.117	0.664	0.5	1.45	0.58	1.16	1.74	2.32	2.9
5	0.246	0.170	0.962	0.8	2.18	0.84	1.68	2.52	3.36	4.2
6	0.340	0.234	1.33	1.0	2.90	1.16	2.32	3.48	4.64	5.8
7	0.457	0.315	1.79	1.3	3.86	1.56	3.12	4.68	6.24	7.8
8	0.557	0.384	2.18	1.8	4.92	1.90	3.80	5.70	7.60	9.5
9	0.703	0.485	2.75	2.3	6.24	2.4	4.8	7.2	9.6	12.0
10	0.879	0.606	3.44	2.8	7.73	3.0	6.0	9.0	12.0	15.0
15	1.70	1.17	6.64	6.1	15.61	5.8	11.6	17.4	23.2	29.0
20	2.75	1.90	10.76	10.8	26.21	9.4	18.8	28.2	37.6	47.0

* Based on friction loss data from standard manufacturers' catalogs.
† Based on equivalent loss of 5.86 ft of ¾-in. Type K copper tubing.
‡ Based on equivalent loss of 4.04 ft of ¾-in. Type K copper tubing.
§ Based on equivalent loss of 22.9 ft of ¾-in. Type K copper tubing.
‖ Based on friction loss curve for ¾-in. Trident meter (manufactured by Neptune Meter Co., New York).

New Appliances

Among the newer water-connected facilities which are causing higher demand rates in the home, perhaps the most common is the automatic clothes washer. Recent models of domestic automatic washers use water at rates of 3–7 gpm. The total volume of water used per washing cycle averages 36–50 gal. Until a few years ago, or water-using appliances in operation at the time.

Another rather new appliance is the domestic type of automatic dishwasher, which uses water at rates of 2.5–5 gpm, depending on the manufacture. A third new water-using appliance is the garbage disposal unit, which uses water at rates of 1.5–2.5 gpm.

The rapidly increasing use of air-conditioning equipment is posing seri-

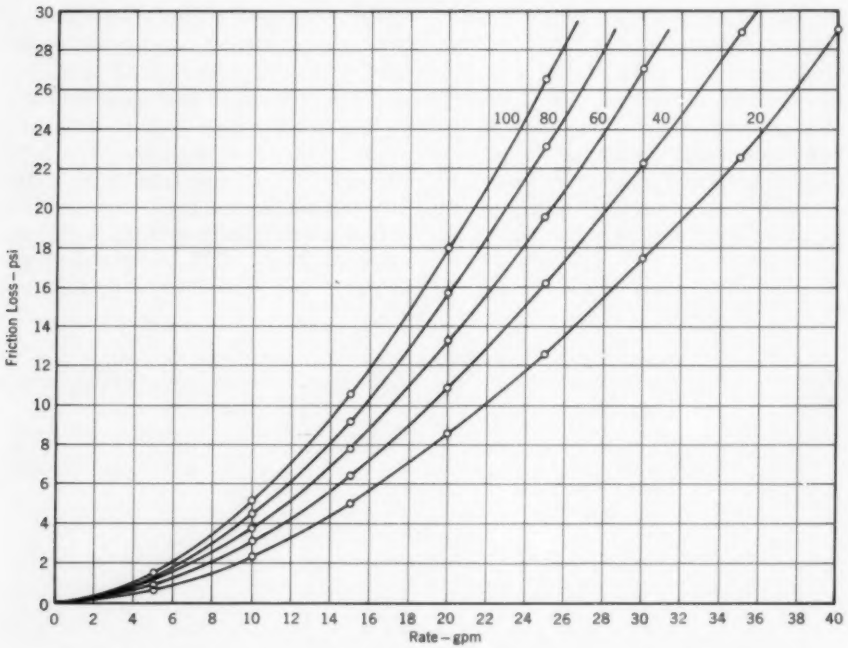


Fig. 2. Computed Friction Losses, 1-in. Copper Service With 1-in. Meter

Friction losses are shown for service lengths of 20–100 ft.

TABLE 3

Computed Friction Losses for 1-in. Copper Services With 1-in. Meter

Rate *gpm*	Service Length—*ft*				
	20	40	60	80	100
	Computed Friction Loss—*psi*				
5	0.7	0.9	1.1	1.3	1.5
10	2.36	3.06	3.76	4.46	5.16
15	4.94	6.34	7.74	9.14	10.54
20	8.46	10.86	13.26	15.66	18.06
25	12.57	16.07	19.57	23.07	26.57
30	17.42	22.22	27.02	31.82	36.62
35	22.6	28.8	35.0	41.2	47.4
40	28.9	36.9	44.9	52.9	60.9
45	36.7	46.7	56.7	66.7	76.7
50	44.1	56.1	68.1	80.1	92.1

ous problems, and various steps are being taken to curb this demand for water, either by requiring the use of water-conserving facilities (such as cooling towers) or by the institution of demand charges to compensate the utility for additional investment needed to handle this heavy load. Home air conditioning has principally involved the use of small air-cooled window units of ¾- or 1-ton capacity which will cool one average-sized room, rather than the complete home. These small units, of course, do not affect domestic water requirements. In many parts of the country, however, particularly in the South, the trend is toward complete home air conditioning through the use of central units. In the past, these larger units, of 3-ton or greater capacity, were water cooled. It is only recently that manufacturers have been able to produce satisfactory air-cooled units of greater than 2-ton capacity.

Air conditioners required for complete home use range in size from 3- to 10-ton capacity. Water-cooled units require about 2 gpm per ton and, when used, impose a water demand of 6–20 gpm, as water-conserving devices are not generally economical in these sizes.

It may be that, as a result of the development of air-cooled air conditioners in these larger sizes, the potential water demand will not materialize. The decision concerning use of air or water-cooled units will probably be determined on an economic basis, and, where charges for water service are low, the cost differential of purchase and operation may favor water-cooled units. Under such conditions, water requirements for air conditioning will continue to require consideration in determining the sizes of service and meter to be installed.

Within the past 12–18 months, rather inexpensive "do-it-yourself" kits

TABLE 4

Computed Friction Losses for 1-in. Service Components *

Rate *gpm*	Fittings and Meter					Pipe Length—*ft*				
	1-in. Corporation†	1-in. Curb Stop‡	1-in. Globe Valve§	1-in. Disc Meter‖	Total Fittings & Meter	20	40	60	80	100
5	0.07	0.04	0.29	0.1	0.50	0.2	0.4	0.6	0.8	1.0
10	0.23	0.13	1.0	0.3	1.66	0.7	1.4	2.1	2.8	3.5
15	0.47	0.27	2.0	0.8	3.54	1.4	2.8	4.2	5.6	7.0
20	0.80	0.46	3.5	1.3	6.06	2.4	4.8	7.2	9.6	12.0
25	1.2	0.67	5.1	2.1	9.07	3.5	7.0	10.5	14.0	17.5
30	1.6	0.92	7.0	3.1	12.62	4.8	9.6	14.4	19.2	24.0
35	2.1	1.2	9.0	4.1	16.4	6.2	12.4	18.6	24.8	31.0
40	2.7	1.5	11.6	5.1	20.9	8.0	16.0	24.0	32.0	40.0
45	3.3	1.9	14.6	6.9	26.7	10.0	20.0	30.0	40.0	50.0
50	4.0	2.3	17.5	8.3	32.1	12.0	24.0	36.0	48.0	60.0

* Based on friction loss data from standard manufacturers' catalogs.
† Based on equivalent loss of 6.67 ft of 1-in. Type K copper tubing.
‡ Based on equivalent loss of 3.85 ft of 1-in. Type K copper tubing.
§ Based on equivalent loss of 29.1 ft of 1-in. Type K copper tubing.
‖ Based on friction loss curve for 1-in. Trident meter (manufactured by Neptune Meter Co., New York).

for underground lawn-sprinkling systems have been placed on the market. Obviously, any extensive system of this type for instantaneous sprinkling of an entire lawn area requires many sprinkler heads and cannot be serviced by usual domestic service sizes.

Unfortunately, the impact of these newer automatic water-connected devices on actual maximum demands has not been sufficiently studied to indicate what the design considerations for service and meter sizing should be. It is reasonable to assume, however, that the 8 gpm demand considered as maximum before widespread use of these automatic devices might be increased to 15 gpm or more. This represents almost a 100 per cent increase, and does not include water for central air-conditioning units. If an air-conditioning unit of 5-ton capacity were also in use, the maximum demand would be 25 gpm or greater.

Determining Service Sizes

If these estimates of potential demands on water service facilities are—as the author believes them to be—reasonably accurate, what size services and meters are required to handle such rates? Obviously, service to any particular customer's premises depends on the following factors: [1] adequacy of distribution piping system; [2] available pressure in main at service location; [3] service line friction losses; [4] meter friction loss; [5] rate of water use; [6] house piping and fixture friction losses; and [7] height from main to highest water outlet.

Although standards for service and meter installations cannot readily be established because of the many variables involved, basic data may be used to assist in the selection of these facilities under given circumstances. If such review indicates that existing practice is resulting in the installation of services which are just capable of meeting present demands, and insufficient leeway is being provided for increased water use by the newer water-connected facilities, this situation can lead only to future service complaints and additional expense for corrective measures.

In order to determine service and meter losses at maximum rates of 8, 15, and 25 gpm, and the likely effect of such rates on adequate service to domestic customers, the author prepared various computed friction loss curves for $\frac{3}{4}$- and 1-in. copper services of various lengths, including the loss through a meter and globe control valve. Although these curves are based on computed values only, they have been checked with actual tests and are considered sufficiently accurate to reflect probable results. Referring to the curves for a $\frac{3}{4}$-in. service with $\frac{5}{8}$-in. meter (Fig. 1), it is found that the total loss at 8 gpm runs from approximately 7 psi for a service 20 ft long to $14\frac{1}{2}$ psi for a service 100 ft long. With pressure in the main at the service location as low as 30 psi, there would be available at the cellar wall (beyond the meter) a minimum of 15 psi to provide for house piping and fixture losses and the difference in elevation to the outlet being used. This does little more than confirm what is already known from experience: that a $\frac{3}{4}$-in. copper service with $\frac{5}{8}$-in. meter has provided adequate service in most instances in the past. What happens, however, if such facilities are called upon to deliver maximum rates of 15 gpm? Unless the distance from the main to the premises is relatively short, such as 20–40 ft, such rates cannot usually be obtained

without prohibitive friction loss. Even with a service length of 40 ft, the loss is over 27 psi, and unless high pressure is available in the main at the service location, the added loss in house piping and fixtures, plus elevation differences, is such that this quantity cannot be made available and a 1-inch service is required. Although the curves for 1-in. copper services (*see* Fig. 2) are based on use of a 1-in. disc meter and show overall losses of 5–10.5 psi at 15 gpm, a $\frac{5}{8}$-in. meter could be installed in the 1-in. service and excessive loss not ordinarily sustained. At a rate of 15 gpm, the $\frac{5}{8}$-in. meter would increase the combined loss about 5 psi to 10 and 15.5 psi, respectively. The data from which the curves shown in Fig. 1 and 2 were plotted are presented in Tables 1–4.

Conclusions

Such results seem to offer sufficient evidence that the generally accepted practice of installing $\frac{3}{4}$-in. services for all domestic customers is not sound. Consideration should be given to installing 1-in. services to meet the actual and potential increased demands of many domestic consumers, even without the use of central home air conditioners which require water for cooling. Services larger than 1 in. may be required for a large number of installations when such water use is added to other home demands.

Results of Cloud-seeding Operations to Augment Municipal Water Supplies

Irving P. Krick

A revision of a paper presented on Oct. 17, 1955, at the Southwest Section Meeting, San Antonio, Tex., by Irving P. Krick, Pres., Water Resources Development Corp., Denver, Colo.

THE steady increase in the population of the United States and the rapid growth of our industries present an alarming problem to the maintenance of adequate domestic and industrial water supplies. The rapid rate of population increase is linked to a growing demand for food, fiber, and industrial development.

The rise in the municipal consumption of water is reflected in a comparison of the average rate of water consumption in the United States for the early part of the century and the present time. Current usage averages 16 bgd, compared with about one-fourth that amount in 1910. The increase, however, is not entirely the result of a growth in population served from 40 to 100 million persons, but is also a reflection of an increase of approximately 60 per cent in the per capita consumption of water. This now amounts to about 160 gpd (*1*).

A higher standard of living and improved sanitation contribute to the rise in water consumption. The sale of water-using appliances, from garbage disposal units, dishwashers, and automatic washers to air conditioners, has increased enormously within a short period, and will very probably continue to increase with the invention of additional water-using devices.

Municipal water departments are becoming deeply concerned about the problem of maintaining an adequate water supply to meet the rising demand, especially in drought years. As there is a limit to the construction of reservoirs and dams, within sound economic practice, additional resources—such as the conversion of sea water to fresh water, and cloud seeding to stimulate rainfall—must be explored. The large-scale conversion of sea water into fresh water is at present not only costly but also difficult to adapt to inland areas where transportation would present a problem. Men, therefore, have turned to another source—the inexhaustible moisture supply in the atmosphere, which is a more economic means of augmenting surface and underground water stocks. This method utilizes the principles of cloud seeding through artificial nucleation to increase natural rainfall. As these principles have been thoroughly discussed in previous articles (*2–4*), mention of them here will be limited to a few essential statements.

Background of Controversy

Since the announcement of the General Electric Company's cloud-seeding experiments in November, 1946 (*5, 6*), similar efforts to increase natural pre-

cipitation have been initiated throughout the world. The evaluation of these results has been clouded by controversy. Experimenters dealing with cloud physics claim that they have seen no evidence of results attaining economic significance; on the other hand, commercial weather modification organizations claim that significant and fundamental value has been obtained from cloud-seeding operations.

To understand the attitudes of both groups, it is necessary to analyze their viewpoints. The experimentalist undertakes a series of tests of limited scale (both in space and time) to obtain useful information on the physical properties and precipitation mechanism of clouds that have been affected by artificial nucleation. Usually these experimenters have merely recorded visual observation of weather modification results. They have not been concerned with targeting their precipitation effects to specified areas.

On the other hand, commercial cloud seeders with knowledge of atmospheric behavior patterns and field experience have developed techniques for targeting seeded effects during the passage of widespread and continuous rain belts. Accurate targeting of seeded effects over a long succession of storms results in precipitation values in the project area measurably greater than those of surrounding regions.

Conclusive assessment depends therefore only upon allowing the operations to continue for a period long enough for sufficiently large values of precipitation to accumulate. The controversy was unfortunately heightened by the unreliable and insensitive nature of the various statistical techniques employed in an evaluation of specific projects.

Finally, in August 1953, President Eisenhower signed into law a bill establishing the Advisory Committee on Weather Control, charged with making "a complete study and evaluation of public and private experiments in weather control for the purpose of determining the extent to which the United States should experiment with, engage in, or regulate activities designed to control weather conditions." On December 9, 1953 the first five members of the committee were appointed—all of outstanding ability in the fields of science, agriculture, and business. Six additional members were selected from interested government departments and agencies.

On February 9, 1956, an interim report was released by the Advisory Committee, stating that superior methodology for evaluating weather control activities had been developed and that in the application of this methodology to commercially operated projects, it had been demonstrated that cloud seeding had produced substantial and economically significant increases in precipitation. The committee staff's statistical evaluations showed that five out of six cloud-seeding projects produced increases in precipitation from 9–17 per cent. The other study produced an inconclusive result. An evaluation, completed after publication of the interim report, showed an increase of higher percentage than those cited, and other projects give promise of showing results of the magnitude cited.

These increases may not seem spectacular but 9–17 per cent increases in precipitation are economically important and create benefit-cost ratios ranging from 4:1 to 20:1—greatly in excess of those which can be realized from conservation projects and or-

dinary water resources development. Here, then, is demonstrable proof of the value of large-scale cloud-seeding operations—proof arrived at by a method which is academically sound. The burden is now on the cloud physicist to explain the last details of why and how cloud seeding works.

tional amounts of moisture from clouds and rainbelts as they pass overhead. As nature very seldom releases more than 5 per cent of the moisture in the clouds, cloud seeding merely increases the rate of fallout of water from a storm during its life history over a specified target area. The process does

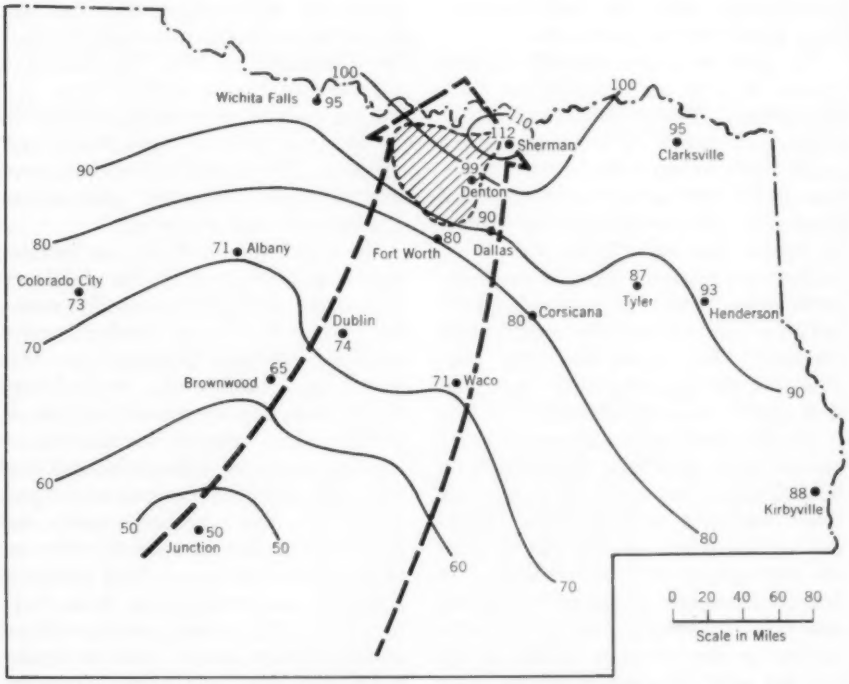


Fig. 1. Percentage Normal Precipitation, Dallas Watershed, Nov. 22, 1952–Apr. 30, 1953 and Oct. 12, 1953–Oct. 12, 1954

Arrow indicates path of principal moisture-bearing air streams; hatched portion shows target area.

Principles of Cloud Seeding

There is no means of increasing moisture from the sky when nature is unyielding. It is only during the occurrence of natural storms that cloud-seeding operations can remove addi-

not remove water permanently from the atmosphere, but merely assists nature in its never-ending cycle of evaporation, transpiration, precipitation, and runoff (*7*).

It has been discovered that a large proportion of the rainfall in temperate

latitudes occurs along zones of interaction between cold polar airstreams and warm tropical or subtropical currents. Atmospheric disturbances contort these zones to form wavelike configurations, marked by falling atmospheric pressure at their crest. These become the migratory cyclones of middle latitudes, sometimes referred to as "low-pressure areas" on weather maps. The warm airstream passes aloft over the cold airstream on the east side of the cyclone. On the west side, the cold polar air underruns the warm current, forcing it aloft. The rising motions in the warm airstream along these two zones of interaction are responsible for the development of the major cloud and precipitation belts, and thus for most of the rainfall recorded in middle latitudes. It has been found that within these cloud masses a large portion of their rain originates as snow at levels where temperatures are colder than freezing. The snow is produced by the growth of ice crystals which form upon dust or other foreign particles present in the clouds (*8*).

The mere presence of these freezing nuclei will not initiate the precipitation mechanism, which occurs only when cloud temperatures are far below freezing, usually around −10°F. If, however, substances which act as freezing nuclei near 32°F, but are not normally present in the air, are dispersed in supercooled cloud formations, a mechanism is provided for inducing additional rainfall from the warmer, moister regions of the clouds. These regions are usually untapped by natural nuclei such as salt, dust, or other foreign particles. Following extensive research, two nucleating agents have been found that fulfill requirements—dry ice and silver iodide. For large-scale operations, silver iodide has an advantage over dry ice because it can be dispersed continuously into an airstream in effective nucleating concentrations over relatively wide areas.

Cloud seeding, in its earlier stages, was conducted by the author and his associates in Arizona, California, and Mexico in 1948 and 1949 by aircraft, but limitations on broad-scale and continuous operations soon became apparent. Considerable effort was expended in 1949 and 1950 to develop equipment capable of introducing continuous and properly controlled cloud-seeding materials into an airstream from the ground. The final result of this extensive research was a ground generator, vaporizing silver iodide. The silver iodide fuel, composed of foundry coke impregnated with controlled amounts of silver iodide dissolved in acetone, is burned at a temperature of approximately 2,500°F. One gram of silver iodide vaporized at this temperature will form about a million billion crystals—each a potential raindrop.

During the past 6 years, the author and his associates have conducted broad-scale cloud-seeding operations in 23 states and ten foreign countries. The operational time logged for these operations amounts to over 400,000 generator hours. Valuable experience gained from these weather modification operations leads to the conclusion that there is every reason to believe that cloud-seeding operations could materially alleviate water shortages and drought conditions wherever they appear.

Case Histories

Although cloud seeding is a new science, it is forging ahead very rapidly because of the tremendous potential it offers an increasingly thirsty

world. The first cloud-seeding operations were conducted for agricultural areas but, in recent years, producers of water power and municipalities have become increasingly aware of their potential.

the city of Dallas. When faced with acute water shortage due to persistent drought, this municipality contracted for cloud-seeding operations in November 1952 for a period of 6 months. Although during the winter months of

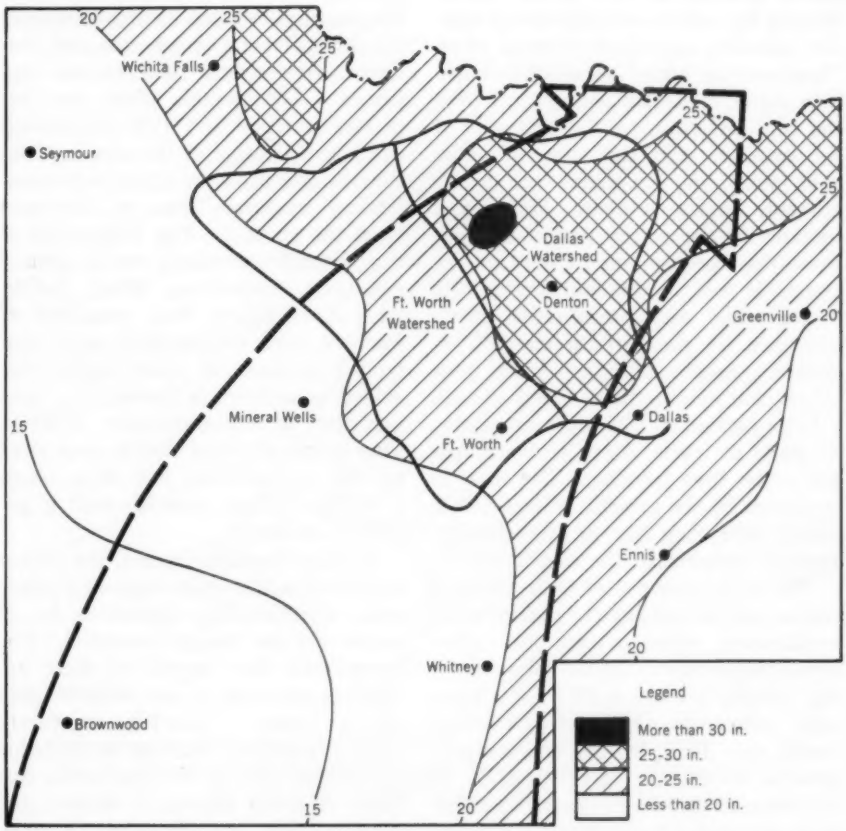


Fig. 2. Rainfall From Sixteen Payoff Storms, Dallas Watershed

Figures indicate accumulated precipitation (in inches) from storms causing major rises in Lake Dallas level.

Dallas, Tex.

One municipality that has relied for the past 3 years on cloud seeding to assure it an adequate water supply is

1952 and early 1953 operations contributed little to runoff, they were extremely successful in improving subsoil moisture conditions in the Dallas drainage area where soil moisture condi-

tions, measured by an independent agency, indicated a moisture penetration of 30 in. or more, compared to 10 in. in surrounding areas unaffected by cloud seeding (*9*). When spring rains came in April and May, producing substantial precipitation, and were augmented by cloud seeding, the previous conditioning of the soil in the target area was reflected in important runoff to the storage reservoirs, whereas surrounding areas, due to dry soil conditions, coupled with less rain-

for another year. The combined results for both operating periods are illustrated in Fig. 1 (*11*).

The principal moisture-bearing airstreams come from the Gulf of Mexico and approach the target from the southwest. When the unseeded sections of Texas, through which the airstream passes before reaching the target, are compared with the seeded section, it is found that the Dallas municipal watershed profited by about 30 in. of rainfall or approximately a 50 per cent

TABLE 1

Payoff Storms, Dallas, Tex., 1953–1955

Year	Significant Rises in Lake Level	Major Storm Periods	Inflow Increase *acre-ft*
1953	Apr. 4–8	Apr. 5	10,250
	Apr. 22–May 1	Apr. 23 and 28–29	36,300
	May 10–18	May 10–12 and 15–17	34,100
	Oct. 23–27	Oct. 22–23 and 25–26	7,800
	Nov. 18–21	Nov. 19	6,800
1954	Jan. 16–Feb. 1	Jan. 15 and 20–21	9,000
	Apr. 29–May 1	Apr. 29–30	3,200
	May 10–19	May 10–12	20,600
	Jun. 7–20	Jun. 14–15	12,000
1955	May 16–23	May 18–20	47,650
	Jun. 7–10	Jun. 8–9	9,650
	Jun. 15–27	Jun. 18–20	15,600
	Total Inflow Increase, 1953–1955		212,950*

* Equivalent to 69.39 bil gal.

fall during these spring storms, showed considerably less flow. Storage as of Jan. 1, 1953, for the Dallas drainage basin was 22,200 acre-ft, compared to the storage on Jun. 1, 1953 of 102,800 acre-ft—a net gain of 80,000 acre-ft during the cloud-seeded period. This amount is almost equal to the combined gain of 93,000 acre-ft during the spring months of the previous 2 unseeded years (*10*).

To maintain an adequate water supply, the city of Dallas renewed its cloud-seeding contract in October 1953 increase over normal precipitation for these two contract periods.

The second renewal of the city's contract started on May 15, 1955. A network of nineteen silver iodide generators was established to insure adequate coverage for the target so that any storm situation characteristic of the region could be satisfactorily influenced by one or more units.

To assess the value of these cloud-seeeding operations to the municipality, the superintendent of the Dallas municipal water department sug-

gested accumulating data for all the storms that showed a significant rise in the lake levels of the Dallas watershed. During these first three periods of operations up to June 1955, a total of sixteen good operational storms reflected a 40 per cent increase in rainfall when the Dallas shed was compared with adjacent drainage basins. Data be assumed that the 40 per cent increase in rainfall also accounts for a 40 per cent increase in runoff over the same period. If the amounts of runoff for these sixteen storms are accumulated, a total of approximately 212,950 acre-ft is obtained. Cloud seeding can therefore be credited with 85,180 acre-ft or 27.7 bil gal.

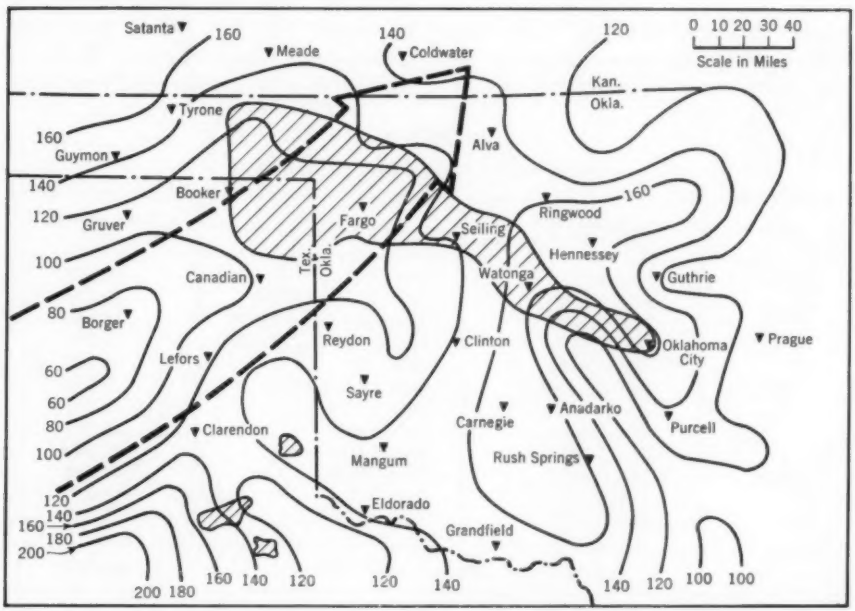


Fig. 3. Percentage Normal Precipitation, Oklahoma City Watershed, Mar. 15–Jun. 17, 1955

As in Fig. 1, arrow indicates path of principal moisture-bearing air streams. Target area (hatched) shows an increase of 50 per cent of normal precipitation. Triangular markers represent generator sites. Small hatched areas in Texas were not part of the Oklahoma City project, but were seeded simultaneously.

for these "payoff" storms are presented in Table 1 and Fig. 2. It should be borne in mind that the number of good operational storms was greater than sixteen, but large amounts of precipitation were required to condition the watershed before appreciable rises in lake level were experienced. It can

Had the city of Dallas decided to obtain this quantity of water from wells, it would have had to drill at least ten deep wells and pump 2 mgd for more than 3½ years to realize a similar amount. The capital outlay would have amounted to about $1,200,000 plus the cost of operation and

maintenance (an amount of over $1,000,000). Thus it would have cost the city roughly $2,200,000 to obtain these 27.7 bil gal from wells, compared to an expenditure of about $100,000 for cloud seeding. This calculation shows a comparative cost ratio of 22:1 in favor of cloud seeding.

On May 15, 1956, a renewal of the cloud-seeding contract started off cloud-seeding operations for another year for the city of Dallas. The 40 per cent differential between the Dallas area and outside watersheds, when the same air masses passed over both (unseeded in the case of Fort Worth, seeded in the case of Dallas), was a persuasive factor in Fort Worth's decision also to join the project in May 1956.

Oklahoma City, Okla.

Another municipality which contracted for a "repeat performance" is Oklahoma City. The first period of operations, November 1953–May 1954, indicated that most of the city's watershed received 75–100 per cent of normal precipitation, while during the same period adjacent areas outside the influence of cloud seeding received only about 50 per cent of normal rainfall. At the end of the operations, the city had received roughly 47,000 acre-ft of water, compared to 24,000 acre-ft during the similar period in 1953 when no cloud-seeding operations took place (*12*). An even more spectacular result was achieved in the spring of 1955, when cloud-seeding operations warranted the removal of water restrictions, thus easing public and civic problems within the city.

The city's reservoir storage consists of Lake Overholzer, Lake Hefner, and allotted space in Canton Reservoir. When cloud seeding started on March 15, 1955, there were only 1,411 acre-ft of water in Canton Reservoir. After 3 months of operations, the impounded storage amounted to 56,200 acre-ft. Within a few days after termination of the contract—allowing for the time lag for water in the upper section of the drainage basin affected by cloud seeding to reach the reservoir—the storage of Canton Reservoir amounted to 119,000 acre-ft. Lake Overholzer and Lake Hefner, with a combined maximum capacity of 93,000 acre-ft, were both filled prior to the end of the cloud-seeding contract from water released from Canton Reservoir. Peak water receipts for 1955 stood at over 200,000 acre-ft. If, at a conservative estimate, cloud-seeding operations are accredited with 25 per cent of these 200,000 acre-ft, then 50,000 acre-ft, worth several million dollars, were the result of the three months of weather modification operations. It was obtained at a cost of about 50 cents per acre-foot. The development of additional water from conventional sources costs about 100 times this figure.

This tremendous gain in impounded storage puts Oklahoma City in the enviable position of having on hand a water supply to cover the next 2½–3 years. The North Canadian River, which had been dry for the best part of the last 3 or 4 years, needed to soak up several hundred thousand acre-ft of water in order to get the high flows it later received. Moreover, soil moisture had deteriorated seriously during the interim of no cloud seeding from the summer of 1954 to the spring of 1955, but the abundant rainfall obtained during the seeded period not only reconditioned the watershed, but gave corollary benefits to the agriculture of the area.

Figure 3 illustrates the benefits received from cloud seeding in the water-

shed of Oklahoma City in 1955. The average percentage of normal precipitation over the watershed area is approximately 130 per cent, compared to areas outside the influence of cloud seeding with an average of about 80 per cent. Thus the target area shows

water supply, contained about 165 mil gal of water, approximately one-ninth of its total capacity of 1,450 mil gal. This was the lowest level ever recorded in Lake McDaniel's history. Fifteen generators were placed in strategic locations to insure complete cov-

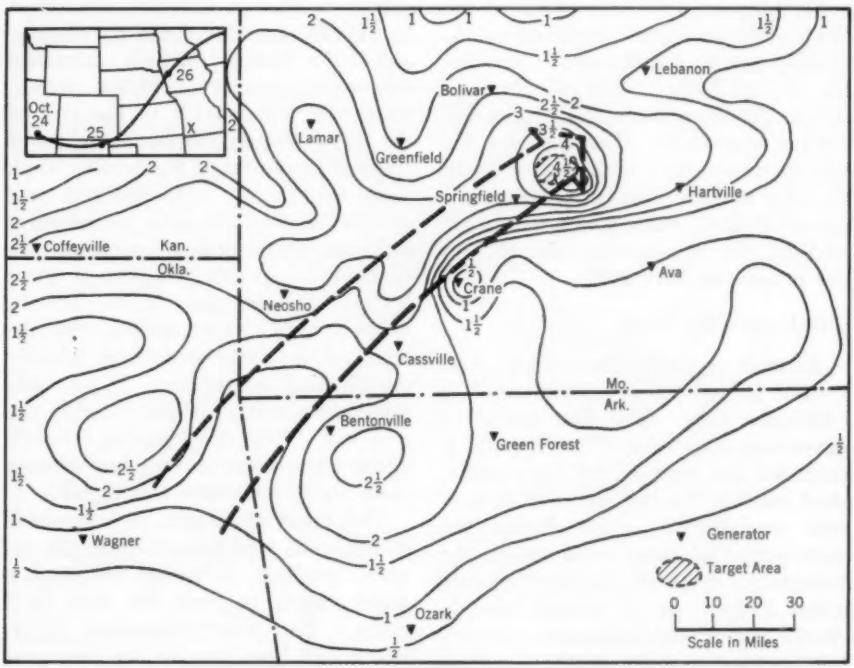


Fig. 4. Actual Precipitation, Springfield, Mo., Watershed, Oct. 25–26, 1954

Figures show rainfall (in inches) for storm period. Insert, upper left, indicates path of storm center.

an increase of 50 per cent of normal precipitation (*13*).

Springfield, Mo.

The Springfield City Water Company contracted for cloud-seeding operations for a 1-year period, beginning Feb. 1, 1954. At that time, Lake McDaniel, the main source of the city's

erage of the watershed. These generators were operated for a total of 1,278½ hr. In full realization of the extremely dry conditions which existed, operations were conducted for every seeding opportunity, regardless of seeding potential.

As a result of these seeding operations, Lake McDaniel was filled and

overflowing from Dec. 23, 1954—so that, at the end of the contract period on Feb. 1, 1955, cloud-seeding services were no longer needed.

An example of the precipitation pattern that often accompanies a cloud-seeded storm, is shown in Fig. 4. This particular storm occurred Oct. 25–26, 1954. The increase in storage from this storm amounted to 631 mil gal, or the equivalent of 1 in. of runoff—43½ per cent of the total capacity of Lake McDaniel (*14*).

The path followed by a storm center during its passage determines, to a large extent, the rainfall pattern which will occur. The position of the target area relative to the storm center is, therefore, of prime importance in any cloud-seeding operation. The project area was not in the most favorable position to receive the maximum rainfall from this storm since the storm center passed far to the north. It is believed, therefore, that the precipitation pattern recorded can be attributed to cloud seeding.

To demonstrate the value of cloud seeding to Springfield, the following figures are quoted from the company's own statistics. During the latter part of the seeding operations, from Oct. 1 to Dec. 24, 1954, the seeding company recorded in its own rain gages 11.08 in. of rainfall. As 1 in. of rainfall on this 42-sq mile watershed equals 2,239 acre-ft, this 11.08 in. accounts for 24,808 acre-ft. Income calculated from metered sales in 1954 was quoted by the Springfield City Water Company at $188.03 per acre-foot. At a very conservative estimate, cloud seeding can be accredited with 25 per cent of these 24,808 acre-ft; or, in other words, with 6,202 acre-ft during the period of October 1 to December 24, 1954. The income derived from this amount alone would be $1,166,162.06, which, in relation to the cost of the program, would mean a benefit-cost ratio of 53:1 in favor of cloud seeding.

It will be realized that when accuracy of targeting of the type demonstrated in the storm of Oct. 25–26, 1954, is repeated over a series of storms, the difference between the seeded target area and the unseeded surrounding areas begins to be very marked. For Springfield, this difference is demonstrated by an independent agency, the USGS in its *Water Resources Review* of December 1954 (*15*). Figure 6, from the USGS report, shows the Springfield area above normal in streamflow and ground water, with a markedly subnormal area surrounding it.

In order to maintain a sufficient water supply and to fill a second reservoir recently completed, the Springfield City Water Company renewed its contract for cloud-seeding operations on Apr. 2, 1956.

Shreveport, La.

In January 1955 the water in Cross Lake, the city's reservoir, had sunk to a dangerously low level. Not only had the two previous years, 1953 and 1954, been extremely dry, but the city had suffered the lowest drawdown in Cross Lake in 25 years—down to 71½ in. below the flow line. The city could not have faced another year without putting its largest plant out of commission.

The city was faced with two possibilities—employing a weather modification program at a cost of $20,000 per year, or laying 20,000 ft of 48-in. steel pipe and constructing a 60-mgd pumping station in order to pump additional water from the Red River. The cost of the plant and pipeline would have

amounted to $400,000 for construction alone. The cost of operation and maintenance must also be considered.

A weather modification program was chosen as the easier and less expensive alternative, and a contract was signed Jan. 11, 1955. By Mar. 20, 1955, the water in the lake had risen to 18 in. above the flow line. On Apr. 15, 1955, it reached 24 in., and on May 23, 36 in. above the flow line. At the end of August, it was still 1½ in. above the flow line—the first time that the water has ever flowed *over the operating level* of the lake so late in the summer. Compared to the cost of construction of another plant and a pipeline to the Red River, the cost ratio is again 20:1 in favor of cloud seeding.

At the beginning of the seeding operations, the lake, which has a total capacity of roughly 23 bil gal (or 70,585 acre-ft), contained only about 9–10 bil gal (or 28,000–30,000 acre-ft) of water. If only 25 per cent of the total increase in water is attributed to cloud seeding, it still amounts to about 10,000 acre-ft of water, which would account for an income of over $1,000,000. Operations have frequently been discontinued for days or weeks at a time, for once the lake was refilled to the operating level no more water was required.

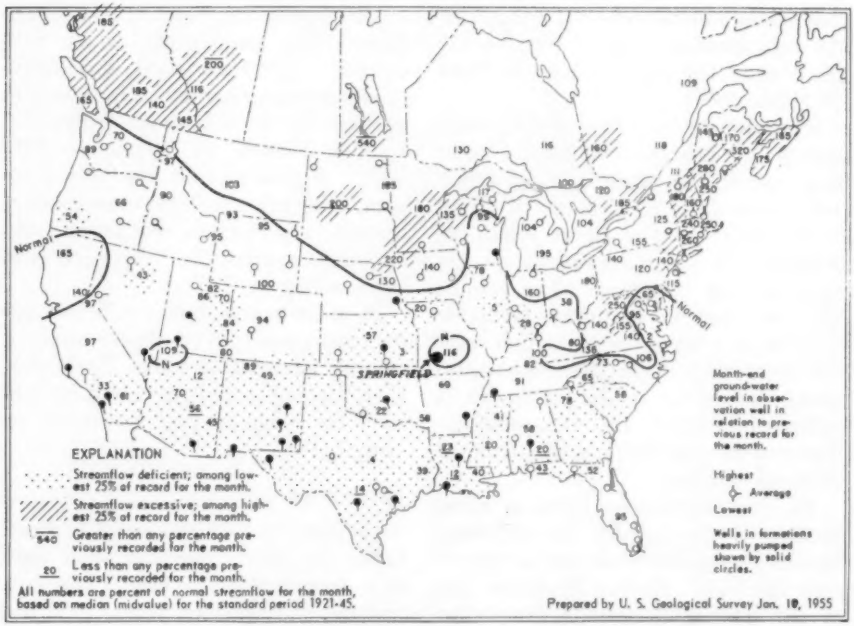

Normal
Normal
SPRINGFIELD
EXPLANATION
Streamflow deficient; among lowest 25% of record for the month.
Streamflow excessive; among highest 25% of record for the month.
540 Greater than any percentage previously recorded for the month.
20 Less than any percentage previously recorded for the month.
All numbers are percent of normal streamflow for the month, based on median (midvalue) for the standard period 1921-45.
Month-end ground-water level in observation well in relation to previous record for the month.
Highest
Average
Lowest
Wells in formations heavily pumped shown by solid circles.
Prepared by U. S. Geological Survey Jan. 10, 1955

Fig. 5. USGS Map Showing Percentage Normal Streamflow and Ground Water for December 1954

Springfield, Mo., area is above normal with regard to streamflow and ground water, although ground water levels were at or near record lows for the season throughout the southern half of the United States.

Incidental benefits to crops accounted for a bumper crop in corn and soya beans. Furthermore, pasture had never before held up so well so late in the season as in 1955. At the present time, Shreveport is in the enviable position of having 2 years' supply of water on hand. There is little doubt that once supplies begin to fall, the city will again turn to cloud seeding for relief.

Denver, Colo.

Cloud-seeding operations to improve Denver's municipal water supply have proceeded over a number of years. Approximately 30 per cent of the city's water supply is derived from snowpack in the Upper South Platte River basin in the Colorado Rockies. The accumulated snow water is released during the following spring to provide runoff into the city's storage reservoirs. Although the resultant runoff varies with temperature, moisture, and wind conditions during the period of melting, it can at least be said that streamflow during April, May, and June is a function of the amount of snow present on March 1.

To assess the result of cloud-seeding operations, it is necessary to compare the snow course data inside the target area with those of surrounding areas, unaffected by cloud seeding. Snow courses inside and outside the target area, with records of 10 years or more prior to cloud seeding in 1950, provide a reference base for making comparisons. As the operations for 1950–1951, 1952–1953, and 1953–1954 have already been described in previously published papers (*16, 17*), only the 5-year operations picture will be discussed here.

In the summary of 5 years of operation, as shown in Fig. 6, it is necessary to consider the various periods of operation in the respective watersheds to interpret properly the data shown. The values refer to the snow water content as of March 1, expressed as a percentage of averages, computed from official snow course data prior to the advent of cloud seeding. These data are regularly published under the joint auspices of the Soil Conservation Service, US Department of Agriculture, and the Colorado Agricultural Experiment Station, Fort Collins, Colo. It will be noted that during the 5-year period 1950–1955 the cloud-seeding operations in the Upper South Platte were conducted for a total period of 18½ months. By drawing a chart which averages the snow water content over the state of Colorado for the 5 years of operations it is easily seen that the maximum of the pattern occurs over the Upper South Platte, showing a difference—conservatively expressed—of at least 30–40 per cent between the target area and outside areas where cloud seeding was carried on for shorter periods. This pattern could not have occurred under natural conditions, as there are no recorded examples of a 5-year precipitation pattern of this character.

It is reasonable, therefore, to assume that the anomalous features, centered in the project, represent the cloud-seeding contribution to snowpack. While the target area shows from 140–160 per cent of normal, the outside areas stand at about the 1950 normal. These values sustain the claim that approximately 25–30 per cent of total runoff, resulting from snowpack, can be credited to cloud-seeding activities, irrespective of the variations in runoff, which occur from year to year.

Total April, May, and June flow at South Platte for 1951–1955 amounts

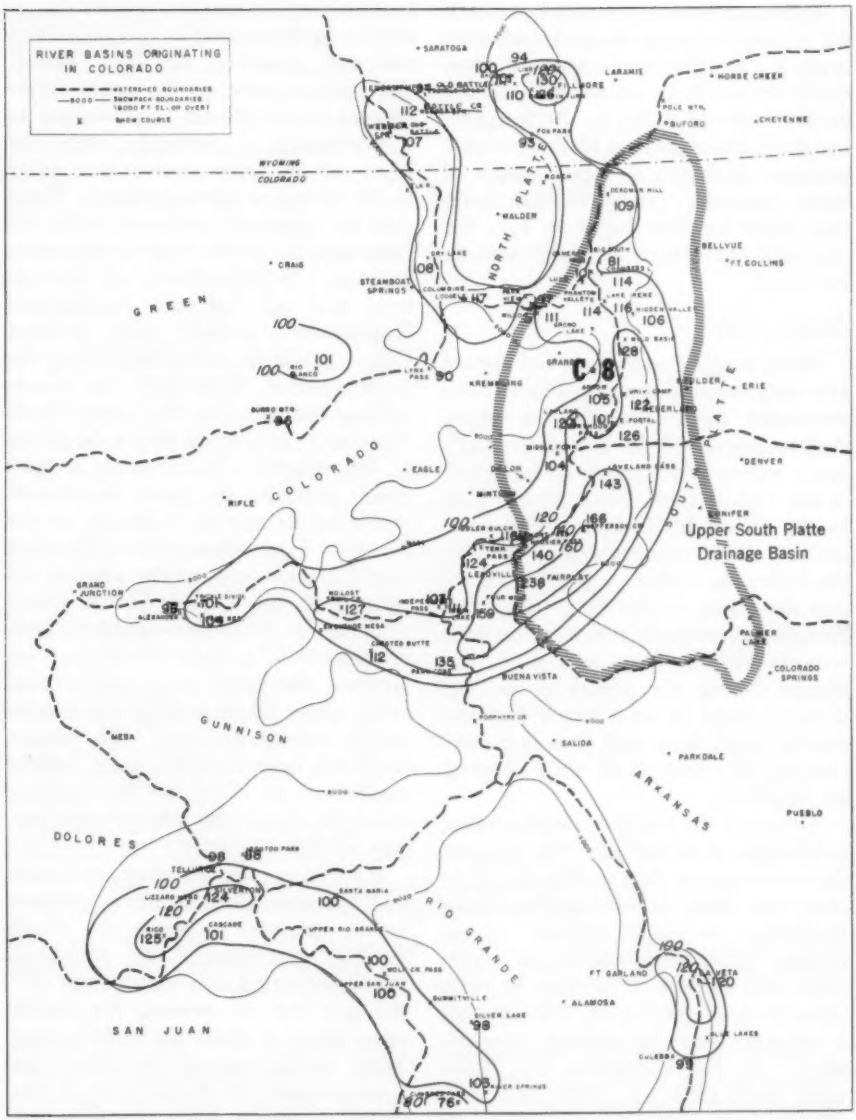


Fig. 6. Five-Year Average Snow Water Content on March 1, Denver Watershed

Figures show average of snow water content for Mar. 1, 1950–1955, expressed as percentage of 1950 normal. During the 5-year period, the following sections were seeded for the total months indicated: Upper South Platte, 8; Western San Juan, 9; Arkansas, 8; West Central Colorado, 6; Rio Grande, 5; North Platte, 4.

to 393,020 acre-ft. Thus, over the 5-year period, cloud seeding contributed approximately 100,000 acre-ft. Water usage during 1954 was 130,000 acre-ft, for which the city received a revenue of something over $6,000,000. The revenue received from the 100,000 acre-ft attributable to cloud seeding would amount therefore to about $5,000,000. The cost of operation, on the other hand, was less than $50,000 or about 50 cents an acre-foot (*18, 19*). To develop additional water from transmountain diversions or other conventional means would cost about 100 times as much.

Conclusions

The unprecedented rate of expansion of our national economy, with its attendant industrial and agricultural demands and increased water consumption, presents a serious problem to our nation.

All municipal and industrial expansion depends on the availability of an adequate water supply, acceptable in quality and cost for both industrial and municipal needs. Because precipitation is the source of both ground and surface water resources, weather modification should be considered as an important means of maintaining an adequate water supply. In planning additional storage, careful consideration should be given the effectiveness of such operations.

From the standpoint of economics, cloud seeding is the least expensive way of getting additional water, as demonstrated by the case histories of Dallas, Oklahoma City, Springfield, Shreveport, and Denver.

Operations, sustained throughout the year, would help to increase both underground and surface water storage at a considerably faster rate than could be expected from natural precipitation. Additional water added to the storage reservoirs would be in proportion to the frequency and intensity of natural storm situations, being greatest during wet years and least during dry years. A sustained program of cloud seeding over a period of years would minimize the need for construction of new storage capacity to meet the ever increasing demand for water.

Acknowledgments

The author is grateful to E. C. Donath, E. M. Frisby, and L. W. Ruid, of the American Institute of Aerological Research, Denver, Colo., and to the following representatives of various municipalities, for the time and thought they have contributed to the preparation of this paper: Elgin E. Crull, City Manager, Dallas, Tex.; Henry Graeser, Superintendent, City Water Department, Dallas, Tex.; Morrison B. Cunningham, Director of Public Works, Oklahoma City, Okla.; Jasper W. Everett, Vice-President, Springfield (Mo.) City Water Department; Fletcher W. Means, Vice-President, Springfield (Mo.) City Water Department; Thomas L. Amiss, Superintendent, Department of Water and Sewerage, Shreveport, La.; and Robert S. Millar, Manager, Board of Water Commissioners, Denver, Colo.

References

1. Foley, F. C., et al. Water in Kansas. Kansas Financial Council, Topeka, Kan. (1955).
2. Krick, Irving P. Increasing Water Resources Through Weather Modification. *Jour. AWWA*, **44**:996 (Nov. 1952).
3. Krick, Irving P. Progress in Weather Control. *Jour. AWWA*, **46**:803 (Aug. 1954).

4. BERRY, FREDERIC A. Evaluation of Weather Modification Experiments. *Jour. AWWA*, **48**:973 (Aug. 1956).
5. SCHAEFER, VINCENT J. Experimental Meteorology. *Z. angew. Math. u. Phys.* (Switz.), **1**:153 (1950).
6. SCHAEFER, VINCENT J. The Production of Ice Crystals in a Cloud of Supercooled Water Droplets. *Science*, **104**:457 (1946).
7. KRICK, IRVING P. Weather Modification and Its Value to Agriculture and Water Supply. *J. Roy. Soc. Arts* (Br.), **112**:4924 (1954).
8. KRICK, IRVING P. Assessing the Value of Cloud-seeding Operations to Water Supply. *Proc. Annual Conf., British Waterworks Assn.* (1954).
9. KRICK, IRVING P. Cloud-seeding Operations at Dallas. *Jour. AWWA*, **45**:1144 (Nov. 1953).
10. HOEFLE, KARL P. Meeting the Dallas Water Shortage. *Jour. AWWA*, **45**:1139 (Nov. 1953).
11. Operations Report for the City of Dallas, Tex., Oct. 1953–Oct. 1954. Rept. No. 232, American Inst. of Aerological Research, Denver, Colo. (1955).
12. Operations Report for the City of Oklahoma City, Okla., Nov. 1953–May 11, 1954. Rept. No. 215, American Inst. of Aerological Research, Denver, Colo. (1954).
13. Operations Report for the City of Oklahoma City, Okla., Mar. 15–Jun. 17, 1955. Rept. No. 282, American Inst. of Aerological Research, Denver, Colo. (1955).
14. Operations Report for Springfield City Water Co., Springfield, Mo., Feb. 1954–Jan. 31, 1955. Rept. No. 257, American Inst. of Aerological Research, Denver, Colo. (1955).
15. Water Resources Review. USGS, Washington, D.C. (Dec. 1954).
16. KRICK, IRVING P. Evidence of Manmade Climatic Change. *Proc. 21st Annual Meeting, Western Snow Conf.*, Boise, Idaho (1953).
17. KRICK, IRVING P. Technical and Economic Aspects of Weather Modification in Relation to Water Supply. *Inst. Water Engrs.* (Br.), **8**:336 (1954).
18. Operations Report for Platte Valley Water Resources Assn., Oct. 15, 1954–May 31, 1955. Rept. No. 277, American Inst. of Aerological Research, Denver, Colo. (1955).
19. Summary Report to Denver Board of Water Commissioners on the Influence of Cloud Seeding During 1951–1955 in the Upper South Platte River Basin. Rept. No. 281, American Inst. of Aerological Research, Denver, Colo. (1955).

Plant Facilities and Human Factors in Taste and Odor Control

Morris B. Ettinger and Francis M. Middleton

A contribution to the Journal by Morris B. Ettinger, Chief, Chemistry & Physics, and Francis M. Middleton, In Charge, Organic Contaminants Unit, both of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

IN 1948, there were 422 water plants in this country serving communities having populations in excess of 25,000 (*1*). Of these communities, 133, with a total population of about 14,000,000, included some provisions for taste and odor control in their water plant. In 1954, there were 570 water plants serving communities having populations in excess of 25,000. Of these plants, 201, serving about 34,000,000 people, included facilities for taste and odor control (*2*). Clearly, taste and odor control is rapidly growing in importance and scope in municipal water plant operation.

Sources of Tastes and Odors

Odors may be attributed to chemical materials produced by organic growths and to the presence of pollutants or other objectionable matter in the water. The distinction is not clear-cut, as the introduction of a pollutant may greatly stimulated the growth of objectionable organisms. Chemical oxidation of carbonaceous material increases the supply of carbon dioxide, which stimulates organic growth. Nitrogen and phosphorus from sewage also stimulate the growth of photosynthetic organisms. The complex phosphate additives of synthetic detergents undergo a very slow hydrolysis which tends to yield a continuously renewed supply of available phosphate for algal nutrition and prevents phosphate concentrations in streams from reaching low levels.

Incredibly small amounts of many odorous materials can cause sensory stimulation. Experiments conducted by the authors have frequently yielded a detectable odor from recovered materials in concentrations of 2 parts per billion and less. Sometimes materials have been isolated (but unfortunately not identified) which could be detected by odor in concentrations as low as 10 parts per trillion. Very substantial odors, therefore, can be caused by extremely minute amounts of such material. In terms of quantities that are easier to visualize, a single teaspoonful of pollutant can impart odor to 1 mil gal of water.

Utilizing adsorption and extraction techniques for concentrating the odorous organic pollutants of drinking-water supplies, it has been found that neutral compounds are usually the most abundant organic pollutants. These neutral organic materials usually have intense tastes and odors.

The second most abundant group of materials is usually the organic acids, which also have intense odors and tastes. Small quantities of other materials have been recovered, including organic bases (which may have a tobacco-like odor), water-soluble compounds (which frequently have caramel-like odors), and a group usually referred to as the "weak acids," which include phenolic compounds, if they are present in the water.

Phenolic compounds are present infrequently and have probably been overemphasized because they are one of the few materials detectable by analytical techniques commonly available to water plant laboratories. Before chlorination, commonly occurring phenolic materials have but little taste or odor. Ordinary chlorination of these materials greatly increases the taste and odor; free residual chlorination destroys the odor.

Characteristics of Tastes and Odors

Odors are subject to seasonal cycles. Industrial pollutants show reasonably well defined patterns of behavior and may be divided into two general categories, depending upon whether they are susceptible or resistant to biological destruction during transportation in surface waters:

1. With pollutants subject to biological destruction, odor intensity is likely to reach a peak during the winter months. Unless the water plant is immediately adjacent to the source of pollution, the peak winter odor intensity is likely to occur when the river undergoes a moderate rise, especially after a period of low water. This is caused by a combination of scouring of bottom deposits and more efficient transportation of dissolved materials. Although the rise in the river increases the amount of dilution water, the reduction in the time of travel between the source of pollution and the point of water consumption is likely to result in an overall increase in the amount of odor-producing material reaching the water plant inlet. Where a river freezes over solidly and perhaps becomes anaerobic in certain areas, maximum odor loads may occur during low-flow periods in the winter.

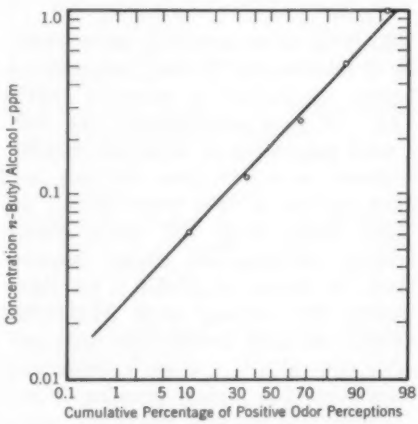


Fig. 1. Characteristics of Operator Response to *n*-Butyl Alcohol

Data used are from 785 observations by 33 operators of odor perceptions at 30°C.

2. Some pollutants are resistant to destruction during transportation in surface waters. (Fortunately, few odorous materials of industrial origin are in this group.) When a water source is polluted by such materials, maximum odor difficulty or other disturbance may accompany any low-flow period.

Algal blooms or spurts of microbiological growth frequently have a

definite seasonal incidence and can be expected at reasonably well defined periods at each locality. Local and regional experience is the best guide available and should be fully explored.

Sometimes algal growth and industrial pollution may take turns as the dominant nuisance in a particular situation. In one water plant studied, phenol from a nearby refinery is present throughout the year, and there is usually a very definite chlorophenolic taste in the water. At certain times of the year, however, algal blooms cause tastes and odors of such intensity that the phenol odors are not noticed.

Characteristics of the Consumer

The food or beverage manufacturer can succeed by pleasing a fraction of the population. People who don't like a product don't buy it, and feel no urge to castigate the manufacturer. The purveyor of public water must try to please everyone. Almost 100 per cent of the population must use his product, good or bad, and even the customer who seeks another source will probably have to pay for public water. Under these circumstances, the consumer is almost eager to exercise his right as a citizen and complain.

It would be useful, at this point, to examine some of the characteristics of the consumer, in an attempt to establish some reasonable goals for taste and odor limits in drinking-water supplies. The average person regards certain tastes and odors very fondly, perhaps with an inordinate and unhealthy affection. The authors, however, have yet to encounter a single taste or odor which satisfied any very high percentage of the population when it occurred in a community drinking-water supply. A person may be very fond of roast beef, buttered lima beans, or cucumbers, and still take a dim view of a glass of water tasting of roast beef, buttered lima beans, or cucumbers.

Some tastes and odors may provoke less unfavorable reactions than others, but this is extremely difficult to measure, and the water plant must operate on the basis that there is no acceptable taste or odor for water. There is no such thing as a threshold odor for a community. Measuring the threshold odor for one man gives a number. Measuring it for five men gives a range. If 200,000 people are used, a very wide range is obtained. Figure 1 shows a log probability graph of 785 threshold odor observations on *n*-butyl alcohol. Population patterns of odor sensitivity may be extrapolated from this graph. The most sensitive 5 per cent of the population is at least 17 times as sensitive as the least sensitive 5 per cent. The 50 per cent man, or median observer, has about one-fourth of the sensitivity of the most sensitive 5 per cent and is 4 times as sensitive as the least sensitive 5 per cent of the population.

Figure 2 gives the response patterns of a twenty-man panel to fifteen different mixed-odor stimuli (*3*). The panel being limited, the ratio of the most sensitive panel member to the panel median (upper 5 per cent man to "middle" man) should be of interest. Here, the lowest value actually observed was 2, the highest 7. The 50 per cent value is about 3. The value of 4, observed for *n*-butyl alcohol, represents a value which would occur or be exceeded about 29 per cent of the time. It is interesting that the most sensitive observer in the twenty-man panel was on the average 11 times as sensitive as the least sensitive man.

Control Procedures

In the consideration of taste and odor control methods for incorporation into design, a complete study of available processes should be made and adapted to the local situation. Flexibility of operations is quite important, as tastes and odors vary widely at different times and require extraordinary treatment only for short periods. Wide-range chemical feeders are essential.

The principal control methods in use are the application of activated carbon, free residual chlorination, combined residual chlorination, and chlorine dioxide treatment. Ozone has found considerable use in Europe but has not been widely used in this country. Aeration is of use where hydrogen sulfide or other highly volatile material is present. It is seldom effective when substantial organic pollution is present.

Activated Carbon

Activated-carbon treatment is the most widely used method for the control of taste and odor. Activated carbon possesses unique adsorptive characterstics and actually removes the objectionable materials from the water. Oxidative methods of control may reduce the odor and taste, but partially oxidized substances of unknown composition may remain in solution. Excessive dosages of carbon will do no harm unless filters are in a condition which permits passing of the carbon. Besides controlling tastes and odors, carbon helps to stabilize sludge, improve floc formation, and remove nonodor-causing organics.

Dry feed and slurry feed are the methods in use for applying carbon. Special equipment for feeding carbon is available. Slurry feeding offers easier and cleaner operation than does the dry-feed method. Carbon can be transported in hopper cars, and, where facilities permit, dumped directly into concrete slurry tanks which feed to the treatment system. The slurry method may also be used to advantage on a smaller scale. Slurry feeding assures that the carbon is thoroughly wet; this is important for maximum effectiveness of adsorption.

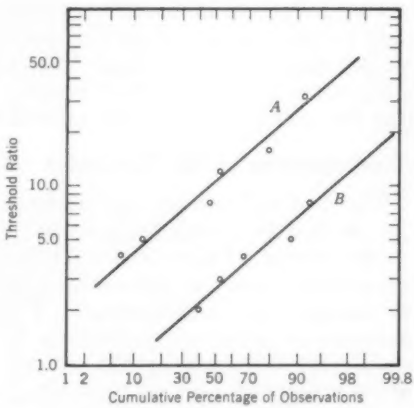


Fig. 2. Some Response Characteristics of Odor Panels

Observations were made by a panel of twenty members upon fifteen different odor-causing materials. Points of Line A *represent ratio of threshold odor of the most sensitive observer to threshold odor of the least sensitive observer. Points of Line* B *represent ratio of threshold odor of the most sensitive observer to threshold odor of the median observer.*

The points of application of carbon will vary with local conditions. Carbon may be applied to the raw water, rapid-mix basin, flocculating equipment, sedimentation basins, conduits to the filters, and the top of the filters. Although adsorption by carbon is nearly instantaneous, a contact time of

5–30 min is helpful. At Oklahoma City, Okla. (*4*), good results have been obtained by use of a baffled retention basin, ahead of flocculation, which is divided in halves that can be operated in series or in parallel. The basin can be washed without affecting operation. The quantities of carbon needed will vary with the type of carbon used, odorous conditions, and other factors. A few parts per million of carbon is the usual dose, but concentrations of 25–100 ppm may be needed at times.

Carbon adsorption is usually most effective at the lowest pH value of the raw water, and, if suitable mixing can be achieved, application of the carbon to raw water is desirable. The carbon may also adsorb some of the chlorine-demanding materials; hence, a saving in chlorine is effected. The higher pH values produced by the softening reactions of lime sometimes "fix" odors, and carbon added after softening may not be as effective as when added at the lower pH. Chlorine is adsorbed by carbon; it is therefore desirable to separate the points of application of the two materials. In general, products formed by chlorination of organics are less adsorbable by carbon than are the materials prior to chlorination, although the reverse has been observed. Combined chlorine is not easily adsorbed by carbon and this property may be used to advantage if chlorine and carbon applications cannot readily be separated. The effects of using carbon with chlorine dioxide and ozone have not been investigated. Adequate experimental testing with the water under conditions proposed for operation must be relied upon for final design criteria.

Where large amounts of carbon are applied to the filters, or appreciable carbon reaches the filters, additional benefits may sometimes be obtained by recycling the filter wash water to the raw-water line going to the mixing chamber, if the carbon is not exhausted.

Oxidative Methods

Chlorination. Marginal chlorination consists of application of enough chlorine to secure a residual without completely satisfying the potential chlorine demand. This treatment tends to develop tastes and odors with phenolic compounds and certain other pollutants through the production of chemical addition or oxidation products. The treatment may in some instances reduce tastes and odors but cannot be counted on for substantial reduction. Griffin (*5*) is of the opinion that where chlorine enhances odor, this effect reaches its maximum in coincidence with the break in the chlorine residual curve.

Free residual chlorination is the addition of sufficient chlorine to meet all of the demand of the water, with the production of a free chlorine residual. Taste and odor from phenolic compounds are usually controlled by this treatment, and many other odorous materials are destroyed or rendered less obnoxious. Reduction is not universal, and free residual chlorination may have to be supplemented by other treatment. More effective disinfection, improved coagulation, algae control, and other benefits accrue from the use of chlorination, and the process should be considered as more than a taste and odor control technique.

The treatment of water with ammonia and chlorine, called combined residual chlorination, prevents the formation of the most intense tastes and odors and may be useful in maintaining a residual in the distribution system. The bactericidal efficiency of

combined chlorine is much less than that of free chlorine. Equivalent results are frequently obtained when chlorine alone is used to treat raw waters containing substantial amounts of ammonia or nitrogenous material.

Chlorine dioxide. This chemical is usually formed at the water plant by the reaction of sodium chlorite with chlorine solutions. At smaller water plants not having gaseous chlorination, chlorine dioxide may be generated with sodium chlorite, hypochlorite, and a mineral acid. It is used primarily for taste and odor control but also serves as a disinfectant and is reported to permit the carrying of residuals throughout the distribution system (*6*). This substance has high oxidizing power and has not been observed to form reaction products of increased taste intensity, such as those caused by the reaction of chlorine and phenolic compounds. Odors caused by natural pollution from algae or actinomycetes, which have been observed to be intensified by chlorination, have been controlled by chlorine dioxide. The material can be added as a pretreatment or as a post-treatment. Cost has largely confined its use to post-treatment. Additional benefits attributed to the use of chlorine dioxide include color removal and precipitation of iron and manganese. There is no readily available simple method for specifically measuring the residual chlorine dioxide in water. Chlorine dioxide has recently found use in control of algae in reservoirs (*7*). It was said to have controlled tastes and odors that might have resulted from the aquatic organisms in the water. In spite of the high cost of chlorine dioxide treatment, it is presently in use by about 100 water plants having difficult taste and odor problems.

Ozone. Ozone is a powerful oxidant and has been used in European countries for several years for taste and odor control and disinfection of water supplies. A large installation is in operation in this country at Philadelphia, and a smaller installation is in use at Whiting, Ind. To form the ozone, equipment is required for cleaning, compressing, cooling, and drying air. The purified air is then ozonized in a specially constructed electrical discharge apparatus. The reason the process has not been used more widely in this country is that a high capital investment is required for generation equipment. In addition, the material dissipates from the water rapidly. Ozone does not form objectionable tastes and odors by reaction with phenolic compounds. Color removal, precipitation of iron and manganese, and disinfection are also attributed to the application of ozone to water. Ozone can be measured by orthotolidine and iodometric methods. It also exhibits strong absorption at 2,537 Å and can be measured photometrically.

Aeration. Aeration has long served as a key step in the removal of sulfides in ground water. At Nitro, W.Va., Haynes and Grant (*8*) have found aeration to be of advantage in treating raw water chronically polluted with volatile chemical wastes. Spray aeration with 110-psi pressure at the nozzles was estimated to be equivalent in cost to treatment with 17 ppm of activated carbon.

This type of treatment obviously will not be advantageous in many circumstances. Haynes and Grant, however, are of the opinion that pressure spray aeration is essential to the production at Nitro of a water of acceptable quality at reasonable cost. Conditions at Nitro are somewhat unusual, but there

are other places, such as Huntington, W.Va., where pressure aeration is used for taste and odor control.

Intake Location

Location of intakes may be quite significant in procuring a good quality water. Where patterns of pollution, particularly by industrial materials, can be traced, suitable intake locations can be selected only after some study. Expenditure for a longer intake line may be justified if pollution sources can be avoided by such action. One instance is known where merely changing the direction of a new intake would have avoided serious problems.

Storage and Impoundment

Raw-water storage would benefit most water works, although few are in a position to provide it. Certainly many of the most odor- and taste-free waters in the country have reservoir sources. Where it is possible to impound water free of undesirable amounts of minerals and waste, a reservoir is of very substantial value.

Where the water source is polluted or has a high mineral content, a large reservoir still can yield very substantial benefits, but much more careful operation is required. If feasible, the reservoir should be designed so that it can be operated selectively for long-term or short-term storage, or even bypassed entirely. The following factors enter into such operation:

1. Time can be allowed for polluted water to undergo biological purification or physical separation of taste-producing contaminants.

2. Slugs of pollution can be allowed to go down the river while the reservoir serves as the source of water.

3. Algal and biological growths can actually cause deterioration of water in the reservoir; hence the need for providing for reservoir bypasses or elective short-term detention.

At Oklahoma City, Okla., Cunningham (*4*) reports much better results with a controllable reservoir (Lake Overholzer) than with a reservoir having inflexible long-term detention (Lake Hefner).

Carbon-feeding Facilities

The engineer has certain well defined general criteria relating to the load on which to base water plant design. Filter area needed is related to volumetric-demand characteristics. Chemical-feeding requirements can be related to measurable patterns of water composition and water demand. Sedimentation basins again can be related to volumetric demand characteristics. tics to which standard design factors apply. There is presently, however, no well defined engineering criterion of the taste and odor load that a plant should be designed to treat.

The variability of the population threshold odor sensitivity has been considered earlier, and the data presented made it quite clear that taste and odor observations based on the senses of one individual have relatively little value as a criterion of community reaction. To get a measure of community reaction, a panel of reasonable size drawn from the local community is required. Such data usually cannot be secured by use of water plant personnel, as few plants have enough people to make up a panel. In many communities, there are organizations, such as the Elks, Rotarians, Kiwanis, and other civic groups, which can be persuaded to send volunteers to make up a panel of reasonable size. Use of such a panel also should stimulate public interest in the water plant, and seed

the community with substantial citizens aware of the difficulties and accomplishments of the water plant.

Another measure which might be of some value would be for water plant operators to get together at meetings such as state gatherings and make observations of the threshold odor on similar samples. Thus, each operator might have opportunity to gage the sensitivity of his own responses against those of his fellow workers and secure some idea of how his senses match up with those of people in general and with his consumers.

Regardless of the difficulty, an intelligent effort can provide a knowledge of local consumer response to odor. Odor has no dimensions and such knowledge in itself provides no index to design or operation. Actually, the telephone gives the water plant operator a continuing report on community taste and odor panel reactions, but this occurs after the water is in the faucets of the citizen.

Of the treatments presently available for odor control, only activated carbon appears to have any reasonable likelihood of universal applicability and success. It is well known that the efficiency of carbons varies, but usually there are only a few carbons under consideration for use in any given locality. Carbon demand in terms of a specific carbon would appear to be a suitable basis for both operational and design criteria.

Most people become dissatisfied with water taste or odor when, in terms of their own senses, the odor of the water exceeds a threshold odor of about 4. A reasonable operational goal would therefore appear to be the production of water which has a threshold of 4 or less for 95 per cent of the population. Consulting Fig. 2 again, it may be seen that if the threshold odor for the median observer is unity, then the most sensitive 5 per cent of the population will have a threshold odor in excess of 4 about 30 per cent of the time. For *n*-butyl alcohol (Fig. 1), which is estimated on the basis of Fig. 2 to show more variation in population response characteristics than 70 per cent of the odor stimuli studied, this criterion will result in satisfaction of 95 per cent of the population.

It is proposed that the odor load be designated as the amount of carbon (in ppm) required to reduce the threshold odor of the median observer to unity. These figures are subject to further examination, but they give a tentative basis for design practice. Provision of carbon feeders and supporting facilities should be made to feed a sufficient amount of carbon to reduce the median threshold odor to unity.

Regardless of whether the odorous material in a raw water be of natural origin, industrial-waste origin, sewage origin, or some combination of the three, odors definitely do fluctuate. It would appear advisable to have equipment of sufficient capacity to feed the required amount of carbon at least 95 per cent of the time. Accordingly, carbon feeders should be geared to all but the most severe conditions. In emergency situations, an operator with a hand truck and a shovel can supplement the facilities provided.

As noted earlier, chlorination can depress or accentuate odor. To be useful, odor testing must take this into account and odor must be observed in finished water processed in a manner which parallels plant operation.

Odor observations should preferably be made with a panel of local observers of both sexes. Where this is not possible, the observer or observers used

should be fairly sensitive, and the relationship of their sensory sharpness to community response established. Such a procedure can indicate the possible success of a treatment process or determine an odor load factor in terms of a specific carbon.

Conclusions

The evident trend in the taste and odor quality of raw water is downward. Estimates of stream pollution in terms of population equivalents show an ever upward trend. Taste and odor loads may be expected to increase more rapidly than loads in terms of "population equivalents" because of many factors, some of which have already been discussed. In terms of provision of facilities for taste and odor control, the designing engineer is fully justified in most circumstances in anticipating increased odor loads per unit volume of water treated. Plant design that does not take cognizance of this factor cannot be considered adequate.

References

1. THOMAN, J. R. Statistical Summary of Water Supply and Treatment Practices in the United States. Pub. 301, USPHS, Washington, D.C. (1953).
2. PORGES, RALPH. Municipal Water Facilities, Communities of 25,000 Population and Over, Continental United States as of December 1954. Unpublished report, USPHS, Washington, D.C. (1954).
3. SETTER, L. R. & WHITFIELD, C. E. The Evaluation of Deodorants for Use in Aircraft Chemical Toilets. Unpublished report, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.
4. CUNNINGHAM, M. B., Director of Public Works, Oklahoma City, Okla. Private communication (Dec. 8, 1955).
5. GRIFFIN, A. E., Tech. Consultant, Wallace & Tiernan Inc., Bellevue, N.J. Private communication (Dec. 30, 1955).
6. Treatment of Water Supplies with Chlorine Dioxide. Bulletin, Olin Mathieson Corp., Baltimore, Md. (1955).
7. RINGER, WALTER C. & CAMPBELL, SYLVESTER J. Use of Chlorine Dioxide for Algae Control at Philadelphia. *Jour. AWWA,* **47**:740 (Aug. 1955).
8. HAYNES, LAWSON & GRANT, WALLACE. Reduction of Chemical Odors at Nitro, W.Va. *Jour. AWWA,* **37**:1013 (Oct. 1945).

Tuberculation of Tar-coated Cast Iron in Great Lakes Water

Thurston E. Larson, R. V. Skold, and E. Savinelli

A paper presented on May 8, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Thurston E. Larson, Head, Chemistry Subdiv.; R. V. Skold, Research Assoc.; and E. Savinelli, Research Assoc.; all of the Illinois State Water Survey, Urbana, Ill. This report was prepared for AWWA Committee 2810 D—Effect of Purification Methods on Water Main Carrying Capacities, whose function is to advise, assist, and supplement the study being conducted on this subject by the Illinois State Water Survey. The study described is being supported by Research Grant 64007 (R) from the National Institutes of Health, USPHS, Washington, D.C.

THE original objectives of the study reported here were [1] to gather operating data by field conferences and observations on water main carrying capacities, methods of treatment of municipal waters, and chemical quality of treated waters at various municipalities where carrying capacity tests have been made, and [2] to investigate by laboratory experiments the effect of "free chlorine" (0.5 mg/l) on the corrosion of steel and cast iron by water.

The first objective was essentially attained, and the second, concerning corrosivity of water to steel, has already been reported (*1*). In that report, basic concepts on the relations of alkalinity and noncarbonate salts to corrosivity were indicated and, for water of Great Lakes character with a chloride-alkalinity ratio of 0.2–0.3 to 1, free chlorine in concentrations greater than 0.4 ppm was shown to increase the corrosion of steel.

Electrical Measurement

At the present time it can be reported that an electrical method has been developed to measure empirically the instantaneous corrosion rates of specimens. This has been highly satisfactory for laboratory testing of bare specimens. Briefly, the method consists of applying current to the specimen in micro amounts and measuring its change in potential against a reference electrode. The change in potential per unit of applied current density ($\Delta E/cd$) was found to correlate quite well with weight loss measurements converted to milligrams per square decimeter per day as shown in Fig. 1. It is, in effect, a measure of film resistance on the metal surface.

The method described above was used to establish the data on the effect of pH on corrosion of steel in water of a specific quality. The rates of corrosion were confirmed by total weight loss of the specimens at the end of the test (*see* Fig. 2). It should be emphasized that this relation is specific only for the type of water and at the velocity indicated.

Subsequent laboratory testing indicated that sodium silicate, in concentrations of 2 and 10 ppm, inhibited corrosion of steel by water containing

2.5 equivalents per million (epm) $NaHCO_3$ with a chloride-bicarbonate rate of 0.4:1 at pH 7.0 and 8.0 and at a constant velocity of 0.14 fps. If specimens were allowed to corrode in water without silica present, however, the subsequent addition of silica up to 20 ppm failed to reduce the corrosion rate in 22 days of testing. These tests were conducted in the absence of calcium.

By providing increased velocity to the test specimens, a decrease in their susceptibility to corrosion was indicated. High rates of corrosion (100 mdd) occurred in waters containing 125 ppm alkalinity and having chloride-bicarbonate ratios greater than 0.2–0.4 to 1, at velocities of 0.085, 0.14, and 0.34 fps; at a velocity of 0.89 fps, however, corrosion at high rates did not occur in waters with a chloride-bicarbonate ratio of less than 0.6:1. In the range of the velocities employed, therefore, the higher velocities allowed greater chloride-bicarbonate ratios before corrosion would take place at rapid rates.

Cast Iron

The part of the study which concerned cast iron had received only superficial attention prior to June 1955. Since then it has received direct attention and has proved to be a very complex problem.

Machined cast-iron specimens were not found to resist corrosion to any significant degree in any type of water under test. Tests made with unground "as cast" or annealed cast-iron surfaces gave evidence of relatively high resistance to corrosion by water of Great Lakes character. It appears that the natural surface skin of iron oxide formed during the process of manufacture is largely responsible for the excellent reputation enjoyed by cast iron as resistant to corrosion.

By correspondence and by visits to foundries manufacturing cast-iron pipe, it was learned that the interior of all centrifugally cast pipe is partially ground for the purpose of reducing roughness prior to the application of the coal-tar coating or cement lining. In this step, most pipe interiors have been ground to the extent of 10–50 per cent of the surface.

These facts indicate that tuberculation results from action of a non-inhibited water on holidays, or minute holes, in those portions of the tar coating which cover the ground portions of the interior of the pipe.

It is of more than incidental interest to note that the production of the tar-coated or tar-sealed cement-lined cast-iron pipe at some plants now represents as much as 80 per cent of the total production. Because there are many miles of tar-coated pipe already in service where treatment plants are proposed or being modified, however, it is apparent that the immediate objective of the present study is to investigate the effect of water quality on holidays in tar coatings covering ground surface cast-iron pipe.

Roughness

As mentioned in the last report (*1*), a number of types of roughness are associated with loss in carrying capacity. The truly tormenting type is that of tuberculation, which can be removed with no visual evidence of metal exposure through the tar coating where corrosion may have occurred. A corollary to this phenomenon is the fact that, at some municipalities, little or no tuberculation has occurred, or did not occur until water treatment was initiated. It may be emphasized that

such experience of "no tuberculation" is reported at some treatment plants where calcium carbonate saturation is not attempted. Laboratory tests, therefore, are now directed toward establishing information on the effect of minor concentrations of corrosives and inhibitors on machined cast iron exposed at minute holes (0.02–0.06 mm) in tar coating. The reason for limiting the exposed area lies in the consideration that minor or nominal concentrations of inhibitors can be considered rather than excessive and abnormal concentrations, as would be necessary for protection of large areas or for uncoated metal.

It has taken months to standardize a technique for duplicating specimens as to coating thickness and hole size. The results are promising.

Preliminary observations indicate that for waters with a pH of 7.2, containing 150 ppm of alkalinity and having chloride-alkalinity ratios of 0.1–1.0 to 1, chlorine or chlorine-ammonia compounds in concentrations of 5 ppm cause evidence of corrosion at a greater percentage of pinholes than that observed in the absence of chlorine or chlorine-ammonia under equivalent conditions at pH 7.2. This is still subject to confirmation.

It should be recognized that up to this time no tests have been made with calcium present, as these studies were designed to provide basic data exclusive of the influence of calcium car-

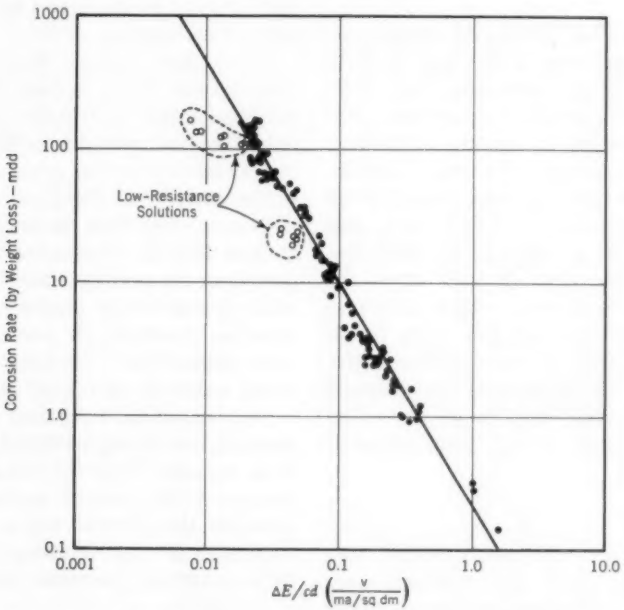


Fig. 1. Empirical Relationship Between Initial Slope of Polarization Curve (Resistance) and Corrosion Rate Determined by Weight Loss

bonate saturation. The literature abounds with information on this principle. There is much data on its effectiveness as well as on its actual or apparent ineffectiveness.

The latest laboratory study on calcium carbonate deposition on cast iron was reported by Werner Stumm (*2*). Stumm's report is somewhat limited for practical application or confirmation by factors carefully pointed out by the author, and it does not consider the relative basic corrosivity of various water qualities, but it is an important contribution to the literature.

In tests on coated cast-iron specimens with 600 pinholes, with a sodium chloride-bicarbonate ratio of 0.4:1 and a velocity of 0.9 fps, only minor differences in corrosivity were noted at pH 7 and 8. When 0.8 epm calcium replaced sodium in this water, a definite decrease in rate, was observed as pH increased from 7.0 to 7.5 to 8.0, although the saturation index at 8.0 was still -0.2. The addition of silica or triethylamine in a concentration of 4 ppm had little added influence. It should be recognized that these observations are still to be confirmed by weight loss measurements.

Galvanic Effect

The problem of protecting uncoated machined cast iron is complex in several ways. On machining, the hard adherent skin is removed, exposing flakes of graphite in a matrix of pearlite or ferrite with phosphides. In the laboratory experiments described here, the smallest hole that could be duplicated in an applied tar coating of 0.05 mm thickness was 0.02 mm. The concentration of exposed graphite on the cast-iron surface was such that 85–95 per cent of the holes exposed graphite as well as ferrite or pearlite. This means that in almost every hole there exists a carbon-iron galvanic cell in which the graphite serving as a cathode accelerates corrosion of the iron. There should be no question but that such a galvanic cell exists, but, for the purpose of providing evidence, carbon rods were coupled with steel specimens, with annealed cast iron and with machined annealed cast iron.

For the steel-carbon couple and the machined cast iron–carbon couple, the potential difference stabilized at 0.5 v after 22 days. For the annealed surface-carbon couple, the potential difference was 0.23 v (this was lower than for the others even though there was one site on the specimen where corrosion occurred at a flaw in the scale or oxide skin). This potential, therefore, actually represents the mixed potential of corroding iron and that of the annealed surface.

Because corrosion by definite galvanic action is present, it would appear that a cathodic inhibitor should be indicated as the corrosion preventive by polarizing or coating the carbon to the protective potential of iron. Calcium carbonate appears to satisfy this criterion for mildly aggressive waters where the area of exposure is at a minimum or where corrosion products are not a detriment. The extent to which silica aids in this process is debatable.

In the analysis of some twenty samples of tubercles and pipe deposits, silica was found to be a significant component, usually consisting of 40–60 per cent of the nonferrous components. This was surprising for Great Lakes waters, because the soluble silica content of plant effluents rarely exceeds 2–3 ppm. Calcium often constituted 15–30 per cent of the nonferrous components, and in about half the samples

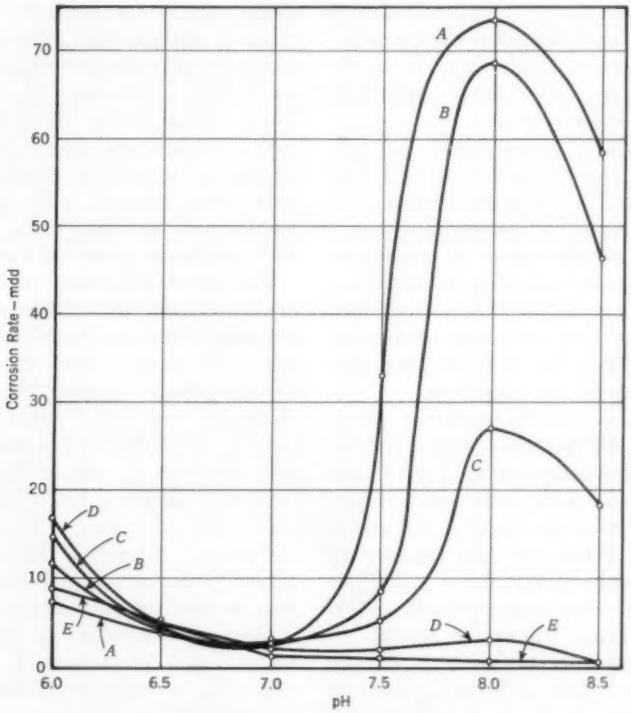


Fig. 2. Effect of pH on Corrosion Rate

The curves indicate results after: A—*16 days;* B—*12 days;* C—*8 days;* D—*4 days; and* E—*2 days. Tests were made on an air-saturated solution with a* $NaHCO_3$ *content of 2.5 epm, NaCl content of 0.5 epm, temperature of 19°–28°C, and a velocity of 0.14 fps. This corrosion rate was calculated from* ΔE/cd.

calcium constituted less than 10 per cent. Sodium aluminate or carbonate or both made up the difference. Samples have not been obtained from a sufficient number of municipalities to provide a true evaluation of this approach.

Conclusion

In essence, this report is a summary of specific findings and conclusions. It may be said that this study has become more clearly defined, necessitating a fresh approach to profit further from the findings made to date. This approach, after months of problems in standardization of techniques, now appears to be bearing fruit. Many negative results have been obtained, but, unfortunately, these are necessary for the elimination of false evaluations.

References

1. Larson, T. E. Report on Loss in Carrying Capacity of Water Mains. *Jour. AWWA,* **47**:1061 (Nov. 1955).
2. Stumm, Werner. Calcium Carbonate Deposition at Iron Surfaces. *Jour. AWWA,* **48**:300 (Mar. 1956).

Report on Toxicity Studies of Cadmium and Chromium

—Clarence F. Decker, C. A. Hoppert, and R. U. Byerrum—

A paper presented on May 8, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Clarence F. Decker, Research Instructor; C. A. Hoppert, Prof. of Chemistry; and R. U. Byerrum, Assoc. Prof. of Chemistry; all of Michigan State Univ., East Lansing, Mich. This report was prepared for AWWA Committee 2610 P—Chromium and Cadmium Solubility and Toxicity.

ONE of the toxic properties of cadmium and chromium is the ability to cause vomiting or emesis. Experimental studies of this property have been performed with cats and, in the study reported here, with dogs.

Cadmium

The lowest emetic dose in cats was found to be 5–6 mg of cadmium per kilogram body weight, while the highest nonemetic dose was 20.4 mg per kilogram. The laboratory work using dogs shows the emetic dose to be 0.5–1.0 mg cadmium (as cadmium chloride) per kilogram body weight. The lowest emetic dose was 5.5 mg in a 11.0-kg dog and the highest nonemetic dose was 26.0 mg in a 26.0-mg dog. Some evidence of vomiting and retching has been observed in animals when there was 5.0 and 10.0 ppm of cadmium in the drinking water.

The chronic toxicity of cadmium has been studied in rats and dogs. Male and female rats were given drinking water, *ad libitum*, containing 0.1, 0.5, 2.5, 5.0, or 10.0 ppm cadmium (as cadmium chloride). Control animals were fed distilled water, and all animals were fed the same diets. Monthly studies were made of blood hemoglobin, red blood cell count, white blood cell count, and differential leukocyte counts. Rats were sacrificed at the end of 6 months, or at the end of 1 year. Liver and kidney tissues were analyzed by the micro-method. After 6 months, tissues from the rats drinking 0.1 ppm cadmium contained no cadmium, but, after a year, there were about 1.7 micrograms of cadmium in kidney and 0.2 microgram of cadmium in liver, per gram of fresh tissue weight. Both tissues from rats drinking 10-ppm solutions contained 20–30 micrograms of cadmium per gram after 6 months, whereas, at the end of a year, there were approximately 40 micrograms and 80 micrograms of cadmium per gram of liver and kidney, respectively. Generally, there was a much greater concentration of cadmium in the kidney than in the liver.

At the end of a year, 2–4 times the amount of cadmium was found in both tissues as was present at the end of the 6-month period. Histological sections were made from representative organs of all animals sacrificed and were examined for evidence of pathology. After 1 year of exposure, no significant evidence of pathology was observed at any of the levels of cadmium studied.

Additional information on the tissue distribution and retention of cadmium has been gained by the use of radio-

active Cd^{115}. After the oral administration of about 2 mg of cadmium in a single dose, approximately 90 per cent of the administered dose was excreted by way of the feces within 72 hr. Less than 3 per cent of the dose was absorbed, and the kidney and liver each contained a little more than 1 per cent of the original dose. The tissue distribution and retention of Cd^{115} after a single intravenous dose (280 micrograms) has also been studied and it was shown that over 60 per cent of the injected dose was found in the liver, the kidney containing about 2 per cent of the dose. Approximately 20 per cent of the injected dose was excreted by the intestine at the end of 72 hr. The cadmium content of the kidney and liver at the end of 2 weeks was the same as at the end of 4 hr, indicating the ability of these tissues to bind cadmium for relatively long periods of time.

The results to date, with respect to cadmium in drinking water, can be summarized as follows: the emetic property of cadmium alone would appear to restrict the upper limit of cadmium to a value below 5 ppm. Significant accumulation of cadmium occurs in the liver and kidneys of rats ingesting water containing between 0.5 and 10 ppm cadmium for about 1 year, but no gross evidence of pathology was observed at these levels.

Chromium

With regard to chromium, the present studies concerned the chronic toxicity of hexavalent chromium in drinking water, and the following levels of chromate were investigated in the albino rat and in the dog: 1.0, 5.0, 10.0, 15.0, and 25.0 ppm. Routine checks on hemoglobin, red blood cell count, white blood cell count, and differential leukocyte count were made at monthly intervals. Careful records were kept of body weight, food consumption, and water intake. Rats were sacrificed either after 6 months or at the end of 1 year, and kidney, liver, and bone tissues were analyzed for chromium. Complete histological studies were made on representative organs, which were examined for evidence of pathology. The results can be summarized as follows: no difference was noted, in comparison with control animals, in body weight, food consumption, or water intake at any of the experimental levels. The histological examination of tissues from rats exposed for 6 months to 1 year at these levels also failed to show any appreciable evidence of pathology. Tissue analysis for chromium at the end of 6 months indicated significant amounts of chromium to be found in kidney, liver, and bone tissue of animals drinking water containing 15–25 ppm of chromate, with bone tissue having the largest amount on a per unit wet weight basis. Tissues from animals ingesting 10 ppm or less of chromate, on the other hand, showed little or no accumulation of chromium.

The work with dogs maintained on the same levels as the rats indicates that, at the levels included in the present study, no evidence of vomiting and retching were observed.

An experiment was recently initiated to evaluate the relative toxicity of hexavalent and trivalent chromium, but no definite conclusions can be made at this time.

The results of the work with hexavalent chromium to date would seem to indicate that the maximum permissible level of chromium in drinking water must be less than 15 ppm of chromate.

Relation of Treatment Methods to Limits for Coliform Organisms in Raw Waters

Graham Walton

A paper presented on May 7, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Graham Walton, Sr. San. Engr., Water Treatment Evaluation Studies, Water Supply & Water Pollution Program, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

NUMEROUS state and other agencies have established bacterial quality standards or objectives for waters used as sources for the production of potable supplies. Many of these standards have been influenced by the USPHS recommendations (*1*), which may be stated briefly as follows: For waters acceptable for treatment by conventional rapid sand filtration with continuous postchlorination, the monthly average density of coliform organisms should not exceed 5,000 per 100 ml; and not more than 20 per cent of all samples examined during any month should exceed that density. The use of auxiliary treatment—prechlorination, presedimentation, or the equivalent—does not permit an increase in the monthly average density of coliform organisms but does permit more than 20 per cent of those samples examined in any single month to exceed 5,000 per 100 ml, provided not more than 5 per cent exceeds 20,000 per 100 ml.

Previous Studies

These recommendations have been based mainly on the work of Streeter and his associates (*2–4*), whose studies involved the collection and analysis of data from fourteen plants located along the Ohio River (1923–24); from seven plants located in Ohio and the Middle Atlantic States (1923–24); from thirteen plants treating waters from the Great Lakes (1926–27); and from 5 years' operation of an experimental plant at Cincinnati, Ohio (1924–29).

All data, except those for the experimental plant, were for plants disinfecting water by postchlorination only. The annual average chlorine dosages applied did not exceed 0.3 ppm for eighteen of the 28 plants. Information on the chlorine residuals in the effluents from these plants is lacking.

The only data involving prechlorination were from 14 months' operation of the experimental plant. During the first 11 months the prechlorine dosage was regulated to provide approximately 0.05 ppm total residual chlorine in the water applied to the filter. This low chlorine residual was maintained to prevent destruction of the biota on the filter. The filter effluent was postchlorinated to provide a total chlorine residual of 0.05 ppm in the finished water. Low chlorine concentrations were considered essential to prevent taste and odor problems.

Greater prechlorination dosages were used throughout the last 3 months.

Average monthly concentrations of 0.36, 0.76, and 0.33 ppm were recorded for the water applied to the filter. This increased chlorine content resulted in considerable destruction and sloughing of the biota on the filter. During the second month the chlorine residual dropped from 0.76 to 0.01 ppm in passing through the filter. Throughout this period postchlorination was used to provide 0.05–0.10 ppm total chlorine residual in the finished water.

TABLE 1

Geographical Distribution of Plants Studied

State	Number of Plants
Georgia	1
Illinois	4
Indiana	1
Iowa	2
Kansas	2
Kentucky	1
Massachusetts	1
Michigan	3
Missouri	4
Nebraska	1
New Jersey	1
New York	1
Ohio	1
Pennsylvania	1
Texas	1
Virginia	1
West Virginia	1
Total	27

In general, the densities of coliform organisms in the raw waters at the plants studied were obtained by presumptive tests of single-tube plantings in decimal dilutions, and were expressed in terms of the "indicated number" (Phelps' index).*

In 1950 Streeter (*5*) made a resurvey of the efficiencies of water treatment plants for the Ohio River Valley Water Sanitation Commission. Data from six plants were analyzed and compared to similar data from these plants for the period 1923–24. Again, the densities of coliform organisms in raw water were determined using single-tube plantings in decimal series and reported in terms of the indicated number. In all cases the presumptive test only was used. In summarizing these data Streeter (*5*, p. 19) states:

> From the standpoint of tolerance, a limiting average . . . density [of coliform organisms] of 10,000 per 100 ml (indicated number) would be adequately safe, but would involve the continued dependence on intensified chlorination as an integral part of every water purification plant.

TABLE 2

Sizes of 27 Water Plants

Avg Daily Production *mgd*	Plants in Group
0.1–1.0	2
1.1–5.0	8
5.1–10	5
11–50	4
50+	8
Total	27

In consideration of the desire to provide safe, palatable drinking water, however, Streeter recommends:

> . . . an ultimate bacterial-quality objective such that the monthly arithmetical average MPN of coliform organisms in the river at all water supply intakes will not exceed 5,000 per 100 ml in any month; nor will exceed this figure in more than 20 per cent of the samples of raw water examined during any month; nor will exceed 20,000 per 100 ml in more than 5 per cent of such samples.

In a panel discussion in 1950, Faber (*6*) presented data for six plants, five of which had average annual densities

* The "indicated number" is recorded as the reciprocal of the conformed or completed findings when the single-portion decimal-dilution method is used.

of coliform organisms in raw water in the range of 5,000–2,056,000 * (MPN) per 100 ml. All used prechlorination. According to the information presented, the densities of coliform organisms in the waters applied to the filters at all three plants reporting such data were zero, and those for the five plants reporting finished-water data were zero. The sixth, a Canadian plant, reported the finished water to be "of safe sanitary quality."

Treatment Processes, 1930–56

Since 1930, pollution has resulted in increased bacterial loadings of raw waters. Many plants are now treating waters having densities of coliform organisms far in excess of the limiting values recommended by the USPHS.

Plant design and operation have also changed. Prechlorination, or at least chlorination prior to filtration, is the common practice. Many plants carry substantial chlorine residuals—as high as 1 ppm free chlorine—in their finished water. Numerous filters have been constructed or rebuilt using coarser sand, and filtration rates of 3 gpm per square foot or higher are frequent occurrences at many plants during summer periods of peak production. The problems caused by mudballs and caking of sand in filters have been eliminated to a large extent by better backwashing. Improvements in coagulation and sedimentation have resulted in common turbidities of less than 5 ppm in influents to filters, and at many plants the practice of filtration to waste to establish a *schmutzdecke* has been discontinued.

Finally, better plant control has been secured through more adequate laboratory equipment, better trained personnel, and improved laboratory procedures. The most important advancement in recent years has been the development of analytical procedures for distinguishing between free and combined chlorine.

It is also to be noted that the current edition of *Standard Methods* (7) recognizes only the most probable number (MPN) for reporting densities of coliform organisms while Streeter used the indicated number (Phelps index). This is significant when one considers that for single-tube plantings in a series of decimal dilutions the ratio of the average monthly MPN to the indicated number is approximately 2.3:1.

TABLE 3

Chlorination Practices of 27 Plants

Total Chlorine Application *ppm*	First Point of Application			Total No. of Plants
	Pre	Intermediate	Post	
0.1–1.0	1	0	1	2
1.1–5.0	10	4	2	16
5.1–10	6	1	0	7
10+	2	0	0	2
Total	19	5	3	27

TABLE 4

Residual Chlorine in Effluent From Plants

Residual Chlorine *ppm*	Plants Reporting	
	Free Chlorine	Total Chlorine
0.0–0.1	1	2
0.2–0.5	2	6
0.6–1.0	3	8
1.0–2.0	1	5
2.0+	0	2
Total	7	23

* Approximately 2.3 times an indicated number of 894,000.

Plant Studies

Although recognizing the numerous problems involved, it was decided to base the present study on existing data available from operating plants. Through the assistance of state departments of health, a tentative list of plants to be considered was prepared. These were selected on the basis of [1] frequent average monthly densities of coliform organisms in raw water in excess of current USPHS recommendations (monthly averages in excess of 5,000 per 100 ml), and [2] the adequacy of the bacteriological data available.

To date, about 80 plants have been visited. Monthly summary records showing average daily data, general information on the design and operation of the plant, and data on bacteriological procedures have been obtained from approximately 50 plants.

Considerable difficulty has been encountered in evaluating the data obtained from different plants. Rather cursory examinations of bacteriological laboratory equipment and procedures for examination of waters for coliform organisms at these plants indicate numerous departures from the 1946 edition of *Standard Methods* (*8*). Probably the most important of these were [1] media of insufficient strength (10–20 per cent of plants visited used a single-strength medium for 10-ml plantings), and [2] failure to transplant 24-hr presumptive positives immediately for confirmation. Other frequently encountered departures were: [1] the use of media other than lactose or lauryl tryptose broth for initial raw-water plantings; [2] prolonged exposure of media to heat in autoclaving; [3] the use of distilled water for dilution water (also use of tap water containing chlorine); and [4] unsatisfactory dilution techniques, such as making multiple 1–10-ml dilutions or the use of cotton-stoppered dilution bottles or tubes which make it impossible to agitate the sample or dilution properly. Although these data are from a select group of plants with respect to laboratory control some of them must be considered of questionable value for use in research.

TABLE 5

Plants Classified by Maximum Annual Density of Coliform Organisms in Raw Water

Raw-Water Coliform Density (Annual Arith. Avg) *MPN/100 ml*	Plants Reporting	Plants With Indicated Percentage Coliform-Positive 10-ml Portions in Plant Effluent		
		0.0	0.1–1.0	1.0+
1,000,000+	1	1	0	0
100,000–999,000	1	1	0	0
50,000–99,000	2	1	1	0
10,000–49,000	15	12	2	1*
5,000–9,900	5	4	1	0
0–4,900	3	0	3	0
Total	27	19	7	1*

* Includes one plant planting 100-ml portions.

Except for residual-chlorine data, which are commonly determined by the orthotolidine procedure and are frequently reported only as free or total chlorine, plant records are generally adequate. To date, data for 24 months from each of 27 plants have been organized sufficiently for study.

The geographical distribution of these plants is indicated in Table 1. All provided at least chemical coagulation, sedimentation, filtration, and disinfection. Several provided additional treatment such as multistage coagulation and sedimentation, excess-lime or lime–soda ash softening, taste and odor control, and corrosion control.

The sizes of these plants are indicated in Table 2, which groups them according to average daily water production for the 2-year period. This ranged from slightly less than 100,000 gpd to more than 100 mgd.

In Table 3 the plants are classified according to the annual average total chlorine application and the location at which chlorine (as chlorine, combined chlorine, or chlorine dioxide) was first applied. For the purpose of classification, prechlorination includes any addition of chlorine providing substantial contact time prior to filtration; intermediate chlorination, the addition of chlorine immediately prior to filtration; and postchlorination, any addition of chlorine after filtration. At least fourteen of these plants normally applied chlorine at two or more locations.

The plants are grouped according to average residual chlorine in the plant effluent in Table 4. In most plants only total residual chlorine was reported, but some reported free chlorine and a few both free and total. It is significant to compare the chlorine residuals maintained at these plants with the low total chlorine residuals (apparently around 0.05 ppm) practiced at the time of Streeter's studies for the USPHS.

Bacteriological Efficiencies

As previously stated, there are many variables in the quality and precision of the bacteriological data obtained from the plant records. In general, raw-water data are based on at least five daily samples per week, with each sample tested by one or more plantings in each of a series of decimal dilutions. Unless otherwise noted, only the presumptive test was used. The presence of one or more indeterminates, which result when all planted portions of a sample are positive, or all are negative, has been indicated in any average including such values by use of an $>$ or $<$ sign, or, if both high and low indeterminates are present, by a $\pm$ sign.

Data for plant effluents are usually based on daily samples taken at least 5

TABLE 6

Annual Average Density of Coliform Organisms in Raw and Finished Waters at Eight Plants Showing 0.1 Per Cent or More Positive Portions in Plant Effluent

Plant Code No.	Raw-Water Coliform Density (Annual Arith. Avg) *MPN/100 ml*	Plant Effluent	
		10-ml Portions Planted	Percentage Portions Coliform Positive
4	$>$ 59,000*	1,250	0.7
7	$>$ 39,000†	1,565§	2.7§
11	28,000*	1,825	0.9
13	$>$ 25,000*	1,585	0.1
23	$\pm$ 6,800	912	1.0
25	$<$ 4,400*	1,825	0.1
26	$>$ 3,500†	7,280	0.1
27	$\pm$ 2,300‡	1,825	0.9

* Confirmed test.
† Planted directly into BGB.
‡ MPN by Thomas' approximation method (9).
§ 100-ml portions planted.

days per week, with five 10-ml portions planted. Unless otherwise noted, the confirmed or completed test was used.

In Table 5 the plants are grouped according to the maximum annual arithmetical average density of coliform organisms in the various raw waters. This was in the range of 2,300–1,700,000 per 100 ml. Each group is subdivided according to the percentage of the treated-water portions planted which were positive for coliform organisms. Data for the eight plants showing coliform organisms in 0.1 per cent or more of all plants showing coliform organisms in the plant effluent for the month in question are given in more detail in Table 8.

The plants are classified according to the poorest monthly quality (with respect to coliform organisms) of the finished water in Table 9. Each group is then subdivided according to the average density of coliform organisms in raw water for that month. As fourteen of these plants reported all plant effluent portions negative for coliform organisms during the entire 2 years of record, they had no poorest months.

TABLE 7

Plants Classified by Maximum Monthly Density of Coliform Organisms in Raw Water

Raw-Water Coliform Density (Monthly Arith. Avg) *MPN/100 ml*	Plants Reporting	Plants With Indicated Percentage Coliform-Positive 10-ml Portions in Plant Effluent		
		0	1–2	2–5
1,000,000+	1	1	0	0
100,000–999,000	6	5	0	1*
50,000–99,000	7	6	0	1
10,000–49,000	11	11	0	0
5,000–9,900	2	1	0	1
0–4,900	[0	0	0	0
Total	27	24	0	3*

* Includes one plant planting 100-ml portions.

finished-water portions planted during the year are given in more detail in Table 6. For coding purposes, all plants have been numbered in the order of decreasing annual average density of coliform organisms in the raw water. It is noted that plants No. 23, 25, 26, and 27, four of the five plants having the lowest densities, all appear in Table 6.

In Table 7 the grouped plants are subdivided as in Table 5, except that the maximum monthly average density of coliform organisms in the raw water has been used. Data for the three

Additional information is given in Table 10 for all plants showing coliform organisms present in more than 1 per cent of the portions listed during the month of poorest-quality plant effluent.

Examination of 2-year data from each of 27 plants treating raw waters having densities of coliform organisms in excess of USPHS recommendations shows that only one plant (No. 23) failed to produce a finished water conforming to the USPHS requirement (*10*) that not more than 10 per cent of all 10-ml portions planted in any

TABLE 8

Data for Three Plants Showing Coliform Organisms in Plant Effluent for Month of Maximum Raw-Water Density

Plant Code No.	Raw-Water Coliform Density (Monthly Arith. Avg) *MPN/100-ml*	Plant Effluent	
		10-ml Portions Planted	Percentage Portions Coliform Positive
7	≥110,000*	130§	4§
11	57,000†	150	3
27	≥ 8,000‡	155	3

* Planted directly into BGB.
† Confirmed test.
‡ MPN by Thomas' approximation method (*9*).
§ 100-ml portions planted.

single month shall be positive for coliform organisms; and that plant failed to conform during only one of 24 months of record.

Furthermore, it is noted that plants No. 23 and 27, those with the poorest-quality effluent, both chlorinated to provide total chlorine residuals averaging only 0.1 ppm.

Only three of the plants studied did not apply chlorine prior to filtration. Data for these plants are summarized in Table 11. Even with relatively low densities of coliform organisms in the raw water, coagulation, sedimentation, and filtration were insufficient to produce a water conforming to the requirements of the USPHS drinking-water standards. The removal of coliform organisms approximated the 98 per cent reduction reported by Streeter (*4*, No. 1565, p. 20) for similar treatment. Thus, disinfection is an essential part of the treatment process whenever the density of coliform organisms in the raw water exceeds 50 per 100 ml.

In contrast to the above, prechlorination, together with coagulation and sedimentation, is very effective in the removal and destruction of coliform organisms. Coliform data for raw water and that applied to the filters for the months of poorest filter influent are shown in Table 12. Nine of the eleven plants produced filter influent waters meeting USPHS requirements (with respect to coliform organisms) for drinking water. Filtration, however, is considered essential to insure removal of particulate matter through which chlorine might not penetrate.

Throughout this study, the coliform bacteria have been used as the criteria for the biological safety of the water. Treatment for the removal of coliform

TABLE 9

Plants Classified According to Density of Coliform Organisms in Raw Waters for Month of Poorest Plant Effluent

Percentage 10-ml Portions of Effluent Coliform Positive	Plants Reporting	Plants With Indicated Coliform Density in Raw Water			
		0–5,000	5,100–20,000	21,000–50,000	Over 50,000
0	14	—	—	—	—
1	8	3	2	2	1
2–5	2	0	0	0	2
6–10	1	1	0	0	0
11+	2	0	1	0	1*
Total	27	4	3	2	4*

* Includes one plant planting 100-ml portions.

TABLE 10

Density of Coliform Organisms in Raw and Finished Waters at Five Plants Showing More Than 1 Per Cent Positive Portions in Plant Effluent for Worst Month

Plant Code	Raw-Water Coliform Density (Monthly Arith. Avg) *MPN/100 ml*	Plant Effluent	
		10-ml Portions Planted	Percentage Portions Coliform Positive
23	±10,000	78	12
7	≷90,000*	130‡	11‡
27	≷ 2,200	155	10
4	≷59,000†	110	5
11	57,000†	150	3

* Planted directly into BGB.
† Confirmed test.
‡ 100-ml portions planted.

bacteria may not be adequate for the destruction of all pathogenic organisms.

Conclusions

Data have been presented showing that adequately designed and well operated water treatment plants can treat raw waters heavily laden with coliform organisms to produce effluents conforming to the bacteriological requirements of the USPHS for drinking water. Coagulation, sedimentation, and filtration, as currently practiced, are inadequate for treating waters having densities of coliform organisms in excess of approximately 50 per 100 ml. Plant superintendents must provide supplementary treatment by continuous and adequate chlorination for any plant treating waters containing substantial densities of coliform organisms.

Some factors to be considered in evaluating a plant's capacity to treat waters with a high density of coliform organisms are the qualifications of the operators, the availability of adequate standby chlorinators, the locations at which chlorine is applied, the residual-chlorine levels maintained in the plant effluent, and the frequency of their de-

TABLE 11

Density of Coliform Organisms in Raw Waters and Filter Effluents at Plants Using Chlorine or Chlorine-Ammonia Post-Treatment

Plant Code No.	Raw-Water Coliform Density (Arith. Avg) *MPN/100 ml*	Filter Effluent	
		1-ml Portions Planted	Percentage Portions Coliform Positive
Year of Poorest Filter Effluent			
10	≷15,000	365	55
18	≷13,000	366*	87*
27	± 1,100	365	1.4
Month of Poorest Filter Effluent			
10	≷ 9,300	31	84
18	≷22,800	31*	100*
27	≷ 2,200	31	10

* Presumptive test only.

TABLE 12

Density of Coliform Organisms in Raw and Settled Waters for Months of Poorest Influents to Filter at Plants Using Prechlorination

Plant Code No.	Raw-Water Coliform Density (Monthly Arith. Avg) *MPN/100 ml*	Influent to Filter	
		10-ml Portions Planted	Percentage Portions Coliform Positive
2	650,000*	145	0
21	23,000	372	2
26	530†	150	12
8	130,000*	130	0
3	99,000‡	42	5
5	9,500†	150	2
14	58,000*‡	300	0
25	≷ 6,000‡	155	12
11	57,000‡	150	3
15	≷10,000	130	3
16	8,200	44	5

* Maximum monthly loading.
† Planted directly into BGB.
‡ Confirmed test.

termination. Special precautions, such as a residual-chlorine recorder and alarm system, are desirable where the chlorine demand of the raw water varies greatly over short periods of time.

Indications are that the current USPHS recommendations with respect to the density of coliform organisms in raw waters acceptable for treatment in modern well operated plants are no longer applicable. It is, however, desired to await completion of this study, as well as of a special project in which selected water plants and the Sanitary Engineering Center are cooperating in a joint study of coliform removal efficiencies measured by membrane filter and MPN procedures, before suggesting any revision to the present recommended permissible limits of coliform organisms in raw waters.

Acknowledgment

The author expresses his appreciation to the many state departments of health, water works, and individuals who have made this paper possible.

References

1. Manual of Recommended Water Sanitation Practice. *USPHS Buls.*, No. 296 (1946).
2. STREETER, H. W. Studies of the Efficiency of Water Purification Processes, Parts I, II, and III. *USPHS Buls.*, No. 172 (1927).
3. STREETER, H. W. Studies of the Efficiency of Water Treatment Processes, Part IV. *USPHS Buls.*, No. 193 (1929).
4. STREETER, H. W.; MOSS, F. J.; & WRIGHT, C. T. Experimental Studies of Water Purification. *Public Health Repts.*, Reprints No. 114, 1170, 1392, 1434, and 1565.
5. STREETER, H. W. Background and Validation—Bacterial-Quality Objectives for the Ohio River. Ohio River Valley Water San. Com. (1951).
6. FABER, HARRY A. Adjustment of Water Treatment to Pollution Loading—Primary Considerations. *Jour. AWWA*, **43**:31 (Jan. 1951).
7. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA & FSIWA, New York (10th ed., 1955).
8. *Standard Methods for the Examination of Water and Sewage.* APHA & AWWA, New York (9th ed., 1946).
9. THOMAS, HAROLD A., JR. Bacterial Densities From Fermentation Tube Tests. *Jour. AWWA*, **34**:572 (Apr. 1942).
10. USPHS Drinking Water Standards, 1946. *Public Health Repts.*, Reprint No. 2697 (Mar. 15, 1946).

In-Service Training Program of the Philadelphia Suburban Water Company

George H. Dann and Kenneth E. Shull

A paper presented on May 10, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by George H. Dann, Exec. Vice-Pres., and Kenneth E. Shull, Director of Public Relations, both of the Philadelphia Suburban Water Co., Bryn Mawr, Pa.

AS the advances made by science and technology increase, so does the need for study and training by professional and skilled workers if they are to keep abreast of the times. The idea of personnel training by industry, within industry, is not new; estimates indicate that over 10 billion man-hours are devoted annually to some kind of training in American industrial concerns. The programs involved vary from the use of employee handbooks and other printed matter to the installation of the equivalent of full scale college curricula. At least two industrial programs are even chartered to grant academic degrees.

During the years of the depression, the utility worker was the envy of the employment field. He had steady employment and few, if any, reductions in salary, whereas practically all other classes of workmen felt the real pinch of those troubled times.

Effects of War

In the latter part of 1939, at the start of the war in Europe, industrial activity began to increase at a rapid rate and continued to accelerate during the next few years. The personnel needs of factories making war materials were such, that, for the first time, a relatively large number of water works personnel left their places of employment to take jobs that were, at the moment, more lucrative but which ultimately offered far less security. In addition, many employees went into the armed services.

During the war years it was very difficult to hire anyone above the classification of laborer. Often it became necessary to place employees who lacked experience, and sometimes ability, in jobs requiring these qualifications. As a result, more careful supervision was necessary. It was soon recognized that some form of special training would be required if these people were to accomplish their assigned tasks in a satisfactory manner. This was especially true of those in the various technical departments.

In the fall of 1941, a course in water treatment was developed by the Philadelphia Suburban Water Company. It was presented in series at each of the company's three filter plants. Classes were usually held in he late afternoon, a time which was most convenient for shift operators. Each class consisted of a 2-hr lecture-discussion period, held twice a week for 7 weeks, or a total of 28 class hours. The fundamentals of water chemistry, bacteriology, biology, and water treatment were presented in a

manner designed to be understandable to those without previous training in science or mathematics. The interest shown by personnel was extremely gratifying; not only were the classes attended by all those who were directly concerned with water treatment, but by many firemen, watch engineers, and maintenance men as well. The size of the classes varied from fourteen at the smallest plant to twenty at the largest plant.

In 1942, the company began to receive employment applications from veterans returning from the European campaign. Many of these men had gone into the service as carefree lads without any definite goal in life. Now they were interested in becoming established in a vocation which would serve as their life's work. The company was glad to give these men an opportunity by placing them in various departments where they might learn while actually doing the job.

In general, the men hired at this time progressed very well. The "on-the-job" training method, however, although it was certain, was an incomplete and slow process with respect to the technical knowledge gained. Moreover, at the end of the war, many employees of the company who had left to enter the service decided that utility work was not exciting enough after their military experience. Some had received specialized training in the service which fitted them for an entirely different kind of work. As a result of this, the company was faced with the question of whether it was going to obtain the skilled water works personnel of the future.

Training New Personnel

A thorough study of the overall situation led to the conclusion that one solution to the problem would be some form of supplementary training for new employees as well as for those already employed. It was felt that such training should provide an opportunity for all employees to obtain additional knowledge about their specific jobs, to acquire the tools necessary to advance to better positions, and to obtain a general education. A decision to organize an evening school was reached following the favorable response to a questionnaire sent to all employees. The school officially came into existence in March 1955. As a first step in the organization of the school, a faculty of six was selected from among company employees. These included the assistant to the executive vice-president, the assistant to the chief engineer, the construction engineer, the project engineer, the auditor, and the superintendent of purification. Three of these men had previous teaching experience in colleges and universities. All had the desired technical background and practical experience.

Program of Courses

Eighteen courses were selected to be given in the fields of engineering and business. They were as follows: Elementary Mathematics; Intermediate Mathematics; Advanced Mathematics; Practical Mathematics; Basic Engineering; Drafting; Surveying; Pipeline Construction; Construction Materials; Power Plant Engineering; Hydraulics; Field Engineering; Advanced Field Engineering; Elementary Chemistry; Water Supply; Water Treatment; Elementary Accounting; and Utility Accounting.

Each employee of the company received a copy of this list of courses, along with a description of the subject matter to be covered, the necessary prerequisites, the instructor's name, and the day and time the course was

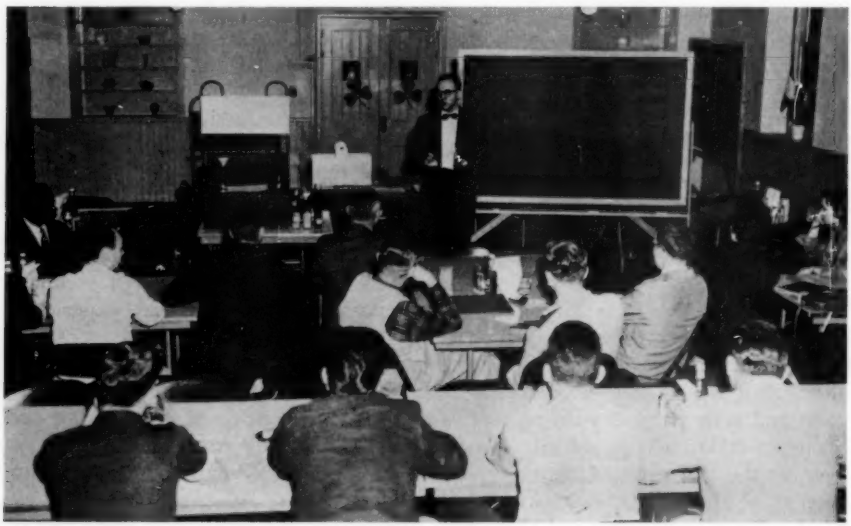
to be given. Course descriptions are illustrated by the following four examples:

101—Elementary Mathematics: A basic course covering addition, subtraction, multiplication, division, fractions, decimals, percentage, rates and proportion, square root, area, volume, weights and measures, simple graphs. Prerequisite: none; 2-hr class; 15 weeks.

209—Field Engineering II: A continuation of Field Engineering I. The course will include surveying, blocking of bends, pipe piers, basic hydraulics, expansion and contraction of materials, calculation of pipe lengths of inclined diagonal runs. Prerequisite: Field Engineering I; 2-hr class; 15 weeks.

303—Water Treatment: A course in water treatment methods as used in the plants of the Philadelphia Suburban Water Company. The course will include theory and practical aspects of: sedimentation; coagulation; filtration; taste and odor control; disinfection; softening; corrosion; iron and manganese removal; boiler water treatment and chemistry; basic water chemistry, bacteriology, and biology; and chemical control tests. Prerequisite: Elementary Mathematics 101 or equivalent; 2-hr class; 15 weeks.

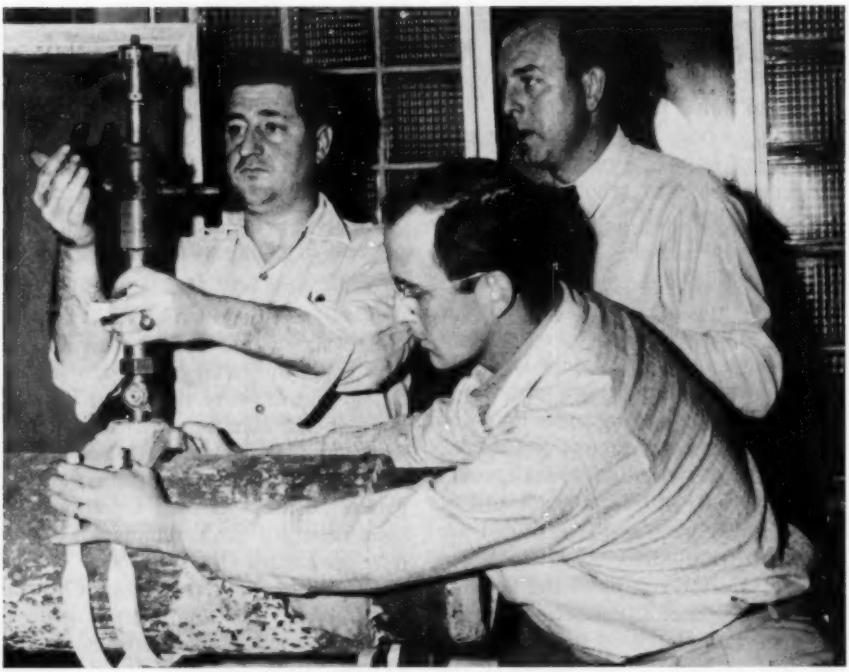
401—Elementary Accounting: A basic course covering the entire cycle of bookkeeping procedure: journalizing, posting, taking a trial balance, preparing working papers and statements, and closing the books. Included also will be the various types of business organizations, special books, voucher systems, controlling and subsidiary accounts, depreciation, reserves, deferred and accrued accounts, bonds, sinking funds, and analysis of statements. Prerequisite: Elementary Mathematics 101 or equivalent; 2-hr class; 15 weeks.



Elementary Chemistry Class in Session

Each course, as planned by the faculty, was to consist of two class hours,

one night a week for 15 weeks—a total of 30 class hours. The questionnaires returned were most encouraging. They indicated that 113 employees (24.5 per cent) were interested in at least one subject. A total of 350 subjects checked was a fair measure of this overall interest.



Students Making Practice Tap in Field Engineering Class

Although most of the subjects received a sufficient amount of interest to be included in the curriculum, it was decided to select the five most popular basic courses to be given during the first spring semester. Thus, those employees who were not fortunate enough to have had these prerequisites for advanced courses were given an opportunity to take them. The courses selected were: Elementary Mathematics, Intermediate Mathematics, Pipeline Construction, Water Supply, and Elementary Chemistry.

The second semester included: Practical Mathematics, Basic Engineering, Field Engineering, and Water Treatment. The third semester included Advanced Field Engineering. Elementary Mathematics, and Basic Accounting.

The school was set up to operate under the same rigorous standards as accredited evening schools. Each course is planned by the instructor in charge, and the subject matter is presented by means of lectures, supplemented by reading assignments from textbooks. Classroom discussion is always encouraged. In many cases fairly complete mimeographed lecture notes are distributed. In addition to reading assignments, homework in-

cludes the solving of illustrative problems. The students' progress in absorbing the subject matter is determined by means of frequent quizzes and a final examination. The final grades, however, are based not only upon a numerical average but also upon general interest and attendance.

Through the first two semesters, 111 students out of an initial enrollment of 195 (56.9 per cent) satisfactorily fulfilled course requirements. It is interesting to note that this group was made up of both male and female employees; of both college graduates and laborers (some of whom had never reached high school); and of both new employees and some who had been with the company for 25 years or more.

Conclusions

Although the Philadelphia Suburban Water Company is a fairly large organization, employing more than 450 people, there is no reason why a similar program, on a more limited scale, could not be developed for a small utility. Certainly the benefits to be gained are well worth the effort.

What are the results of the training program to date? Just recently a department head reported that the school has had significant effects upon the operation of his department. To some extent, people in lower classifications have developed through the courses they have taken to such a degree that they are now able to perform more highly skilled operations. They are already filling higher classifications and will continue to do so in the future. A number of unsolicited letters have been received from various students. Some of their statements follow:

> I think the night school is one of the best things that the company has done until now.
>
> Courses—good; teaching—good; coverage of material—fine; explanation and presentation—excellent. I appreciate this opportunity to acquire knowledge that would otherwise have been rather difficult to obtain.
>
> A very good plan for all concerned.
>
> I appreciate the thoughtfulness of management in giving us a chance to better ourselves.

Some time ago an AWWA committee stated that the objectives of a well rounded training program should be: [1] to improve the group level of occupational efficiency; [2] to acquaint the group with new developments; [3] to develop among the members of the group a concept of their individual responsibility to the community; [4] to develop among the members of the group a better understanding of human relations; [5] to improve the general level of knowledge and efficiency; and [6] to stimulate a continuing desire for self improvement.

It is felt that these objectives are being met by the Philadelphia Suburban Water Company's night school.

Training Water Works Personnel

Joint Discussion

A joint discussion presented on Oct. 6, 1955, at the North Central Section Meeting, Minneapolis, Minn.

Objectives and Techniques—*W. Van Heuvelen*

A paper presented by W. Van Heuvelen, Director, Div. of Water Supply & Pollution Control, State Dept. of Health, Bismarck, N.D.

THE public, and even officials of municipal government, are often unaware of the duties and problems confronting the water works superintendent or the training and experience necessary for the efficient exercise of his duties. Although experience is the greatest teacher, adequate technical background and training are fundamental. Unfortunately, a technically trained superintendent cannot be expected in small systems as long as the present salary schedules prevail. Training facilities must therefore be available to assist water works operators in the many aspects of their jobs. These facilities should offer a variety of means of securing training which will fit the particular needs of each operator and superintendent.

Of fundamental importance in a training program is the superintendent's or operator's desire for continued learning about his job. If the operator does not have this desire to learn new aspects of his work, training programs are of little value. A good training program should arouse the interest of water works personnel in further training in their field. An important part of a training program is to develop this interest in water works employees so that they have more enthusiam for their jobs and the desire for more knowledge about their field.

There are today many possibilities for training in the water works field. Most of these are loosely organized and poorly coordinated, but if the operator has a real desire for more training many opportunities are available. This article will discuss briefly a number of the various means by which operators and superintendents can secure some degree of training.

Plant Visits

Often the state health department's training of water works employees is centered on visits to individual plants. During such inspection tours, special effort is frequently made to visit new plants, or plants with new superintendents. Technical information and advice are supplied to water works men during these visits. Health department technicians are available for special problems and in times of emergencies. Although these visits are not strictly of a training nature, special problems,

if solved, can be handled by the local operator the next time they arise.

Another advantage of including visits to individual plants as part of a training program is that the plant personnel use their own laboratory and equipment and develop proper techniques with their own tools. If laboratory training is provided only at a university or large center, equipment available might be quite different from that found in the average water treatment plant.

Although considerable training can be developed by these plant visitations, water departments cannot depend solely on this source. Most health agencies have neither the time nor the men to provide adequate consulting services. One advantage of this practice is that the individual problems of a particular plant and operator are considered. Often formal .raining courses repeat information well known by many superintendents attending these courses.

Conferences and Courses

State and regional water works conferences provide some training. Through the presentation of technical papers and the informal exchange of ideas among operators, new methods and facts can be learned. Water works employees should consider attendance at such conferences an important part of improvement in their jobs.

The North Dakota Department of Health holds 1-day refresher courses in each of its health districts for operators of small communities. These operators have common problems, the discussion of which in open forum can help develop proper methods of operation and maintenance of water works. It is believed that these 1-day courses are of much value to the small-town operator and should be a part of any training program.

Commercial companies and their traveling representatives provide much valuable training to operators of large, as well as small, plants. These men are specialists in their own line and can give the local operator much valuable information.

Current water works magazines furnish a valuable training service. Technical articles on problems of operation and maintenance and new developments in water treatment appear each month. Some publications have serial articles on various aspects of water works operation. These materials, when prepared by outstanding men in the water works field, are a real training aid. Again, the value to each operator will depend upon his own interest in improving his abilities for the job.

Undoubtedly the establishment of formal schools or correspondence courses for water works operators is highly desirable. Such schools can cover a wide variety of subjects. They should be staffed by consulting engineers, experienced water works superintendents, and health officials, so that a well rounded program and point of view can be developed.

There are available many agencies, individuals, and methods for adequate training of water works employees. The real need is for an organized system of providing this training to the operator. Finally, some method of acknowledging the operator's accomplishments in a training program is also needed, so that these efforts will be recognized by his superiors and by the public.

In-Service Programs—*Lawrence E. LaLonde*

A paper presented by Lawrence E. LaLonde, Administrative Asst. to the City Engr., Minneapolis, Minn.

In-service training is a grossly ignored subject, generally, and particularly in technical settings, such as the water works industry, where management tends, possibly justifiably, to concern itself disproportionately with the mechanics of operations to the detriment of administration, as used in the broadest sense.

It should be emphasized at the outset that *training is a definite function of management.* The primary responsibility of management is, of course, to carry out the principal functions of an agency as well as it possibly can, but whatever training is necessary to reach this primary objective should be provided by management. Needless to say, training of some kind necessarily takes place in most job situations, but it is the responsibility of management to see to it that this training is systematic, not haphazard; that it is efficient, not wasteful; and that it is effective, not useless.

In evaluating the merits of any formalized training program, one consideration should be held uppermost in mind: the success of any training program is dependent, in the last analysis, on the attitudes of employees and on their desire to learn. Employees can be required to sit in conference after conference, given reams of material to read and study, lectured incessantly and indefinitely, and generally go through all the motions—yet no training will take place unless the employees actively participate in the training process. And this, quite simply, can be brought about only by making the learning process interesting.

If a proposed training program is to be made systematic and effective, the specific training needs must first be determined. The two basic training needs might be described as: [1] the need for training new employees and [2], the obvious corollary, the need for training present employees.

Training of New Employees

Within the framework of a civil service system, the training of a new employee should be one of the concomitants of the probationary period, but whether this is recognized or not, there is a definite, undeniable need to make sure that the new employee has a clear understanding of his duties and how he is to perform them; to whom he is responsible, and for what. The author recalls an actual administrative situation in which an extremely well qualified individual was asked to accept the position of comptroller of a large midwestern city. For the first 6 months after accepting the position he did virtually nothing but watch and listen. He indulged in no broom-wielding tactics or rash of orders from "on high"; for the most part he merely asked questions. And of all the questions that he asked the more than 300 employees in the office, the most revealing were: "Who is responsible to you?" and "To whom are you responsible?" Why were these questions revealing? Because a surprisingly large number did not really know to whom

they were responsible, and a lesser (but still surprisingly large) number contended that x number of employees were responsible to them, which, in fact, was not the case. In other words, there were more bosses than bossed. This is a situation that is much more likely to occur in a large organization, but there is a moral for management in this little anecdote, and that is: make *sure* that your employees know to whom and for what they are responsible and who is responsible to them.

Beyond this, there is need for the new employee to learn certain information about the organization as a whole. A program to satisfy this need is commonly known as a "general orientation training program," and its scope and content depend, in large measure, on the educational level of the employees at whom it is aimed. Usually, however, a general orientation program involves discussion of the following:

1. *General conditions of employment.* Here, of course, should be discussed the rules and regulations governing the agency as to hours of work, sick leave and vacation, political activity, and all other personnel policies and practices which affect the employees in question.

2. *Basic organizational structure.* Under this category, the new employee should be oriented as to who does what under what circumstances.

3. *Overall purpose and objectives of the organization.* The new employee should be shown how his job fits into the overall job pattern of the entire organization. It should be explained to him that his job, however modest, is necessary to the effective operation of the organization, emphasizing the resultant need for him to perform his job to the limit of his abilities.

4. *Grievance procedure.* Needless to say, it is extremely important that the new employee be convinced that if he has a complaint, there will be ready opportunity for him to be heard fairly.

Training of Present Employees

The second training responsibility is that of training present employees. There are four primary aspects or objectives to this matter. The first of these is the need to increase the effectiveness of the employee in his present position. Many managers are misled into thinking that because an employee has been doing a certain kind of work for a long period of time, he is necessarily doing a good job. Actually, he may have mislearned the job originally, or he may be backsliding through lack of interest or challenge—and, after all, who is doing his job so well that he cannot do it better?

The second objective of training present employees is to prepare a certain employee or group of employees for promotion. Of the several different types of training possible, this type is most generally neglected, yet it becomes of paramount importance when the employee is being offered a career in the public service. Regardless of promotion policies, however, the need for training employees for this purpose becomes acute when the work is specialized—perhaps to the point of being peculiar to a single agency—and requires long experience to master. In cases of this kind—and the water works industry affords a prime example—the agency has no alternative other than to develop within its own staff the experts it cannot recruit from outside.

The third aspect of training present employees is retraining. Briefly, retraining is necessary whenever an in-

creased range of versatility is required of any specific employee or group of employees, and it should not be overlooked that such employee versatility creates a personnel reservoir upon which management can draw during emergencies or peak loads, thus contributing significantly to greater flexibility and continuity of operations. Retraining is also sometimes necessary when a competent employee is dislocated from a particular division of operations because of a significant change in the work load, and must be transferred to a job which is radically different from that which he previously held.

The fourth primary goal of training present employees is the development of what, in personnel circles, is sometimes referred to as "organization fitness." This might be defined as an understanding and appreciation, on the part of the employees, of the organization's objectives. It is characterized by breadth of view, open-mindedness, a readiness to learn, recognition and abhorrence of inefficiency, and a sincere desire to serve the public. In effect, then, "organization fitness" is a frame of mind, a particular habit of thought, and, as such, not easily achieved. If it is ever to be achieved, however, it will be only through the utilization of systematic, efficient, and effective training procedures.

Training Methods

Once the agency's specific training needs have been determined, it is necessary to choose the particular forms and methods of training to be used. Of the several methods and techniques available, the practicality and usefulness of each must be evaluated in terms of specific local needs. Some of the more effective and popular training methods are the following:

1. *Group training.* Two commonly overlooked forms of group training are the regular staff meeting and the periodic assembly of all employees in an organization. The latter device, especially, provides an opportunity to foster a unity of feeling and purpose that should be the goal of any organization. Inspection tours and field trips are forms of group instruction that can be valuable to the employee, provided the trips are well planned and managed.

2. *On-the-job training.* Some kind of supervisory assistance, particularly for a new employee, is taken for granted. The problem is to get the supervisor to plan his instruction and to go about it in an organized and systematic fashion. It has been suggested that four steps should be followed in on-the-job training: [1] demonstration by the supervisor; [2] trial by the beginner; [3] correction of mistakes; and [4] follow-up effort, in which each of the other steps is repeated until the correct work habits are firmly established.

3. *Supervised practice.* The familiar "understudy" method is the most common type of supervised practice.

4. *Rotation of assignments.* This technique is used primarily to increase the versatility of the employee, but occasionally for the general purpose of orientation as well.

5. *Audio-visual aids.* It has been said that one picture is worth a thousand words; if this is so, it behooves management to look into the possibility of utilizing films. Many of these can be obtained free of charge from certain large companies, and others are available in the public libraries of the larger communities.

6. *Circulation of manuals, bulletins, and correspondence.* One obviously has to be discriminating about the nature of correspondence that is to be circulated; as for manuals and bulletins, to be valuable training devices, they must be attractive and readable.

7. *Other methods.* There are other useful but more subtle methods of training which will not be discussed here, but the author would like to suggest that every program to increase employee participation in policy development or work development is in many respects a training implement. Every assembly or printed circular or procedure that creates an opportunity for such participation is, in effect, training supervisors and employees in human relations and in the habits that build morale and productivity.

Conclusion

The author is not unaware of the many obstacles, budgetary and administrative, that stand in the way of realizing a systematic, efficient, and effective training program within most organizations. Everyone should take stock of himself and make sure that it is not indifference or inertia that precludes the establishment of some sort of training program in his own organization. Nor is it possible any longer to excuse the absence of some sort of training program in one's own organization by rationalizing that it is an unprofitable frill, a bit of window dressing. If it were, private industry would not engage in it as extensively as it does.

External-Corrosion Problems in the Water Distribution System

Leon P. Sudrabin

A paper presented on May 10, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Leon P. Sudrabin, Director of Eng. Services & Development, Electro Rust-Proofing Corporation, Belleville, N.J.

THE well established physical properties of metals used in water distribution piping remain, in the absence of corrosion attack, virtually unchanged with time. This quality of metals in piping is most fully realized by the integration of properly adapted corrosion control measures into the design, construction, and operation of the water distribution system.

The best method of corrosion control becomes apparent after the corrosion causes, mechanisms, and all other relevant physical and economic factors existing on a specific subsurface structure are understood. This paper is intended as a guide in systematizing the engineering approach used for corrosion control.

Corrosion control on a subsurface structure is achieved in three steps: diagnosis, treatment, and measurement of the protective state.

Diagnosis

Corrosion activity can be divided into two broad classifications:

1. The corrosion of subsurface structures by *stray* direct currents which flow in circuits grounded at more than one point or which flow in subsurface structures purposely made part of the d-c circuit.

2. The corrosion of subsurface structures by *galvanic* currents originating between discrete areas of oxidation and reduction reactions. Galvanic currents are the effect rather than the cause of corrosion.

This distinction in the corrosion caused by *stray* current or resulting in *galvanic* current flow is used to identify the form of corrosion activity occurring on a subsurface structure. Stray-current effects can usually be more easily identified than the galvanic form of corrosion. The pipe-to-reference-electrode potential and pipeline current flow changes are directly related to variations in the d-c load. This characteristic of stray-current effects is used in a method of network calculation to establish quantitatively the bonding or other corrective requirements (*1*).

Stray Current

Stray currents are usually manmade (with the exception of magnetic earth currents). An isolated buried pipe section in a stray-current potential gradient will collect current (protective effect) in the area of the more positive ground-to-pipe potential and lose current (corrode) in the area of less positive ground-to-pipe potential.

The harmful effects of stray currents can be minimized or even converted into protective effects by one or more of the following methods:

1. Locate and eliminate the cause of the stray-current effects.

2. Locate the area in the distribution system from which stray currents, collected on the piping, tend to return to the earth. Install a metallic bond of adequate size to return all the current collected on the distribution system to the negative bus of the d-c stray-current power source. This stray-current drainage will provide a net protective effect to the buried piping. Gas pipelines and electrical cable bonded to the water services tend to provide electrical continuity through the system even though the water mains have nonconducting joints. (In many cities where d-c railway systems have been discontinued, severe corrosion on subsurface structures is now being experienced. The stray-current bonding system had provided effective cathodic protection to the water distribution piping.)

3. In instances where it is not practical to drain stray-current effects through bonds, galvanic anode or impressed current can be superimposed upon the pipeline to oppose the harmful stray-current effects.

4. The intensity of stray-current corrosion on a distribution system can be minimized by isolating the system into short lengths of piping insulated from each other. As the potential gradient traversed by each pipe section is usually small, the net current collected and then lost on a pipe section usually results in little stray-current corrosion.

The insulation of the distribution system into short lengths has the advantage that it is easily accomplished with the standard bell-and-spigot (lead or sulfur jointing compound) and mechanical joints. Its chief disadvantage is that the protective effects on local-cell corrosion by stray-current control cannot be achieved until the pipeline is continuously bonded.

In some instances of very high ground-potential gradient, the stray-current corrosion effects on short isolated pipe lengths are severe at the end from which the stray current flows through the soil to the adjoining length of pipe. (*Note:* Iron is more than 10^8 times as conductive as soil.) Low-resistance bonds should be brazed across the resistive joints to provide a continuous metallic drainage path to the negative bus of the d-c system.

Stray-current drainage or rectifier-impressed current cannot be applied to a pipeline of insulated sections until the resistive joints are bonded. This is difficult to accomplish under paved streets and the decision to use an isolated or continuous metallic pipe system should be made after consideration of the external-corrosion causes and the influence of neighboring pipe systems.

Because d-c railway or electrified-mine systems are sometimes supplied with power from more than one location and changes in load centers occur, polarized relay switches must often be used to drain current in one direction only, from the distribution system through the bond cable to the negative bus of the d-c power source.

Stray Current From Cathodic Protection

Cathodic-protection rectifier-impressed current systems may introduce a stray-current problem on distribution piping within the potential gradient influence of the anode bed or the protected pipeline. The rectifier stray-current effect can be identified by measuring a change in the structure potential to a reference electrode which

is directly associated with the instant that the rectifier is turned on or off. In the author's experience, most operators of water distribution systems are not adequately concerned with the harmful effects possible from impressed-current cathodic protection applied to structures near their piping. Cooperative tests within the framework of an electrolysis committee (*2*) or directly by those applying cathodic protection would minimize this corrosion cause.

Stray Current From Welding

Direct-current welding operations in shipyards and industrial plants have resulted in intense corrosion effects on subsurface structures. In a paper mill, the negative terminal of the welding machine was found connected to the adjacent steel framework of the building. The positive cable, several hundred feet in length, supplied welding current to work grounded to a structural member of a neighboring building. As the buildings were grounded at several points, parallel paths through the earth existed.

Penetration of a buried water pipeline outside the building in which the welding generator was located occurred within a few months after its construction. Variations in line current and pipe-to-reference-electrode potential on the pipeline observed on a 24-hr recording voltage chart, were found to be related to the welding operations. The stray-current effect on the pipeline was eliminated by grounding the negative terminal of the welding machine to only one point, the work.

Electrical Grounding System

The National Electrical Code requires grounding of residential a-c power to water piping. Corrosion caused by alterenating current of commercial frequencies is reported to be less than 1 per cent of corrosion from an equal amount of direct current (*3*). Bellassai (*4*) found that induced alternating current on a pipeline was not rectified. An oscilloscope showed that the induced a-c voltage had a perfect sine wave.

Alternate-current grounding may result in long-line galvanic-current flow through the wire grounded to several subsurface structures. This grounding practice makes it difficult to insulate water service piping into short sections.

Galvanic Corrosion

Galvanic corrosion is commonly viewed as consisting of dissimilar metals coupled together in a corroding electrolyte. This condition occurs in a water distribution system where a bronze-bodied valve or copper pipe is coupled to iron piping. The effect of this galvanic couple is to cause corrosion of the iron pipe (anode) and protection of the bronze or copper (cathode).

Nonuniformities on the surface of the iron pipe produce galvanic cells of intensity comparable to an iron-copper couple. Recent studies (*5*) show that mill scale (magnetic iron oxide), removed from the underlying iron in order to eliminate the effects of the iron–mill scale couple, is more cathodic than copper and requires more current for polarization.

In the iron–magnetic oxide corrosion system, the anodic process at the airfree surface is $Fe^0 - 2e \rightarrow Fe^{++}$ and the cathodic process is the reduction of oxygen on the oxide surface, $\frac{O_2}{2} + 2e + H_2O \rightarrow 2OH$.

The potential of rust scale (magnetic iron oxide) removed from a cast-iron water-cooled liner of a diesel engine and the graphitization product on cast-iron pipe have been measured to be + 0.05 v against a copper sulfate reference electrode. The open-circuit voltage between an iron surface in an airfree environment at a pH of 9.0 and magnetic iron oxide in an aerated environment approaches 1.0 v (*6*). Steel pipe embedded in concrete is cathodic to steel pipe in soil.

must first be directed toward their treatment.

The interpretation of pipe-to-reference-electrode potential measurement must be related to the length of galvanic-corrosion current flow lines occurring on the pipeline (*7*).

Long-Line Galvanic-Corrosion Current

A pipeline behaving as a closure circuit between widely spaced anodic and cathodic areas (*see* Fig. 1, Line *C*) furnishes an example of long-line galvanic-corrosion current. Long-line

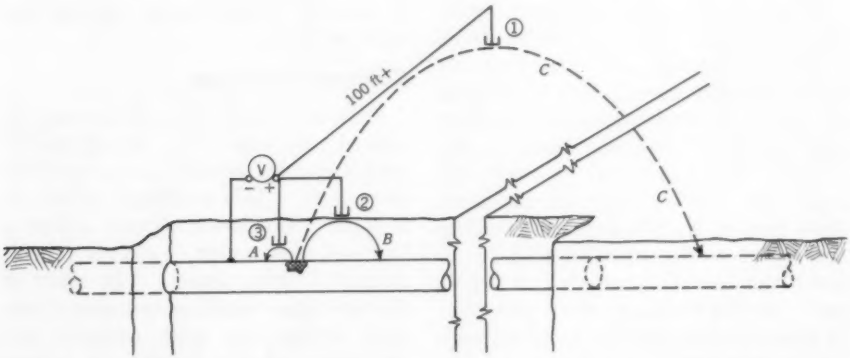


Fig. 1. Location of Reference Electrode to Measure Protective Potentials on a Pipeline

Potentiometer is indicated by circled V. Numerals show: (1) remote copper sulfate electrode; (2) surface copper sulfate electrode (over pipe); and (3) copper sulfate electrode near pipe surface. Line A *represents local-cell corrosion current; Line* B, *intermediate galvanic current; and Line* C, *long-line galvanic current.*

The indirect manifestations of galvanic-corrosion activity (potential and current) on subsurface structures are quite steady. The influence of intense climatic changes is cushioned by the natural resiliency of subsurface environments.

Severe stray-current electrolysis usually makes it difficult to identify galvanic corrosion. Where stray-current effects are dominant, efforts

current flow is identified by conventional measurement of ground surface potential gradient or pipeline current flow techniques. This long-line corrosion current flow may be controlled by an insulating joint at the junction of dissimilar pipe sections. Examples of such joints are: concrete covered, with bare pipe; copper, with steel pipe; old, with new pipe; well aerated, with poorly aerated pipe.

Intermediate Galvanic-Corrosion Current

An example of intermediate galvanic-corrosion current is to be found in the corrosion current flow in a system of anodic and cathodic areas (*see* Fig. 1, Line *B*) whose ground surface potential gradient is discernible to a reference electrode positioned at intervals of 1 ft or greater along the pipeline.

Local-Cell Corrosion Current

An example of local-cell corrosion current flow can be found in a system between close anodic and cathodic areas (*see* Fig. 1, Line *A*) whose potential gradient is not discernible to a reference electrode on the ground surface; that is, when the electrical boundary of the corrosion current flow line is close to the pipe surface. Local cell pitting is the most difficult to detect and to control.

The pipe-to-reference-electrode potential observed includes the vector summation of the effects of long, intermediate, and local-cell corrosion currents. The local-cell corrosion current may not be discernible and must always be suspect. Such local corrosion cells may exist on surfaces indicated to be cathodic by measurement of ground surface potential gradient.

Examples of local-cell corrosion include the following cases:

1. A 72-in. bare steel water main in the Northeast had been buried for 40 years in a marsh. During backfilling, the overlying peat had been distributed throughout the clay surrounding the pipe. Localized pits, randomly positioned over the pipe surface, were associated with the areas of peat contact. The potential gradient on the ground surface—where the resistivity was 6,000 ohm-cm—indicated the 600 ft of pipe in the marsh area anodic to adjoining pipe. Intermediate and local-cell corrosion currents were not identifiable by ground surface potential gradient, as the depth of pipe cover was 10 ft. The flow of long-line corrosion current in the pipeline closure circuit at both ends of the 600-ft pipe section represented less than 25 per cent of the total corrosion experienced.

2. Leaks had occurred on a bare unprotected pipeline in sand of high resistivity (50,000 ohm-cm dry; 30,000 ohm-cm after rain) within 3 years after construction. In the areas of corrosion activity, small masses of talc-like consistency were found distributed throughout the sand.

Anomaly in Pipeline Corrosion

An unusual illustration of the greater severity of local-cell corrosion was found in a midwestern refinery (*6*) where complete penetration of 400 ft of 4-in. hot-water (170°F) line occurred within 2 years in sand-backfilled areas. The attack was not so evident on the pipes in areas backfilled with loam and cinders. The initial observations made are given in Table 1.

The pipe-to-reference-electrode potentials remained steady and no potential gradient effects related to stray current were noted. The line currents measured did not account for the intense attack in the sand areas.

The investigation was continued by removing samples of the crust of corrosion product and soil adhering to the pipe on representative areas and examining them. Findings are presented in Table 2.

It is believed that the porosity of the sand allowed alternate immersion and exposure to air on the hot pipe surface, resulting in rust scale (magnetic iron oxide) formation. This

highly cathodic magnetic iron oxide scale, loosely attached to the underlying bare metal, is part of an intense local-action corrosion cell. The long-line current flow represents a small part of the total corrosion experienced.

The loam-cinder backfill, being less porous, tends to maintain a more uniform vapor environment around the heated pipe and thus retards the formation of the highly cathodic magnetic oxide scale (*see* Table 1).

Protective Measures

Local-cell pitting (*see* Fig. 1, Line *A*) is the most severe and usually represents the largest portion of the corrosion loss experienced on a bare buried pipeline. It is not practical to insulate the small individual anode surfaces from the adjoining cathode surfaces in order to interrupt the short-circuit corrosion current flow through the pipe metal.

Corrosion current flow through the soil can be retarded by the use of resistive coatings applied to the pipeline. On new construction of services and distribution main, a coating meeting AWWA standard specifications (*8, 9*) for coal-tar enamel protective coatings for steel water pipe should be applied. Such coating should be reinforced with a wrap. The application specifications should meet the requirements demanded by the pipeline site conditions.

There is no single environmental measurement which will be sufficient assurance that a coating is not required. Local pit penetration, within 5 years, of gas and oil pipelines (bare) buried in soils of 50,000–1,000,000 ohm-cm resistivity is now being frequently experienced.

Corrosion of pipe at the flaws which inevitably occur in coatings or on bare pipe can be controlled by the use of the cathodic protection principle—the application of a direct current to prevent or retard corrosion on a metal surface.

The protective current may be provided by galvanic anodes coupled to the structure or by current flow impressed upon auxiliary anodes from an outside power source. The protected surface does not recognize the source of the protective current. Thus, economics and practical operating conditions will determine the best protective system to use. The protective-current requirements are usually very small for a well coated piping network.

TABLE 1

Initial Observations in Pipeline Survey

Item	Leak Area	Nonleaking Area
Backfill	sand	loam-cinders
Resistivity—*ohm-cm*	3,000–10,000	2,300–10,000
Potential of pipe to copper sulfate reference electrode on ground over pipe—*v*	−0.05 to −0.10	−0.5 to −0.6
Pipeline current—*amp*	0.4	0.4

Measurement of Protection

The engineer must be assured that the method used to control corrosion is effective by some meaningful measure.

R. M. Burns (*10*) has described the work of the corrosion engineer as "the task of preserving the metallic state in surroundings where variables are com-

plex, compounded, and uncontrolled." This complexity of corrosion is illustrated by the fact that seemingly identical pipelines in the same service and environment do not experience identical corrosion problems. The performance and the requirements for any of the basic methods of corrosion control vary from place to place and time to time. For these reasons, it is the author's opinion that evaluation of the performance of protective measures must be made on the actual structure at regular intervals.

Among the useful basic values is the protective potential of iron, established by Schwerdtfeger and McDorman (*10*) to be − 0.77 v measured against a saturated potassium chloride–calomel reference electrode (equivalent to − 0.85 v measured against a copper sulfate reference electrode). This is the open-circuit potential of an iron electrode in an airfree environment at a pH of 9.0.

Brown and Mears (*12*) show that cathodic protection is complete when the cathodes have been polarized to the open-circuit potential of the anodes.

The author (*7, 13*) has shown that the cathodic polarization of any single corrosion current flow line is entitled to an *IR* drop through the electrolyte equivalent to the maximum distance of the trajectory of the current flow line normal to the pipeline. To illustrate the concept just presented, three examples which intentionally exclude outside effects such as shielding and interference from foreign structures will be examined briefly. (When outside effects do occur, they must be considered by the corrosion engineer.)

The relation of the copper sulfate reference electrode location and the control of corrosion currents on a bare pipeline, protected from a remote ground bed, is illustrated in Fig. 1.

1. The corrosion effect of long-line current *C* is controlled when − 0.85 v is measured at Location 1. The effects of corrosion currents *A* and *B* are lessened.

2. The effects of corrosion currents *B* and *C* are controlled when − 0.85 v is measured at Location 2. The effects of corrosion current *A* are lessened.

3. The effects of corrosion currents *A*, *B*, and *C* are controlled when − 0.85 v is measured at Location 3, near the pipe surface.

TABLE 2

Later Observations in Pipeline Survey

Item	Leak Area	Nonleaking Area
Appearance	red coating on blackened ⅜-in. sand crust	white powder (insoluble) in ½-in. loam-cinder crust
pH of distilled-water extract	8.2	5.15
Response to magnet	highly magnetic	slightly magnetic
Reaction with dilute HCl	CO_2 gas evolved	no gas evolved; white powder insoluble

Subsurface Potential Calculation

It is difficult to measure the potential of the pipe to a reference electrode positioned close to its surface. The potential of the pipe to a close reference electrode can be calculated from ground surface potential measurements.

Howell (*14*) showed that the current collected (*I*) per linear foot of pipe can be calculated from the ground surface gradient normal to

the pipeline, as follows:

$$I = \frac{42e}{\rho} \quad \ldots\ldots\ldots (1)$$

in which e, the average surface voltage drop for spacing of ten pipe depths normal to the pipeline (mv), is equal to $\frac{e_1 + e_2}{2}$.

The potential of the pipe surface (I) to the close reference electrode is expressed as follows:

$$E_r = E_s + 0.5e\left(\log\frac{d}{r} - \log\frac{2d-r}{d}\right) \quad \ldots (2)$$

in which: E_r is the pipe-to-reference-electrode potential over pipe at a distance r from the pipe axis (mv);

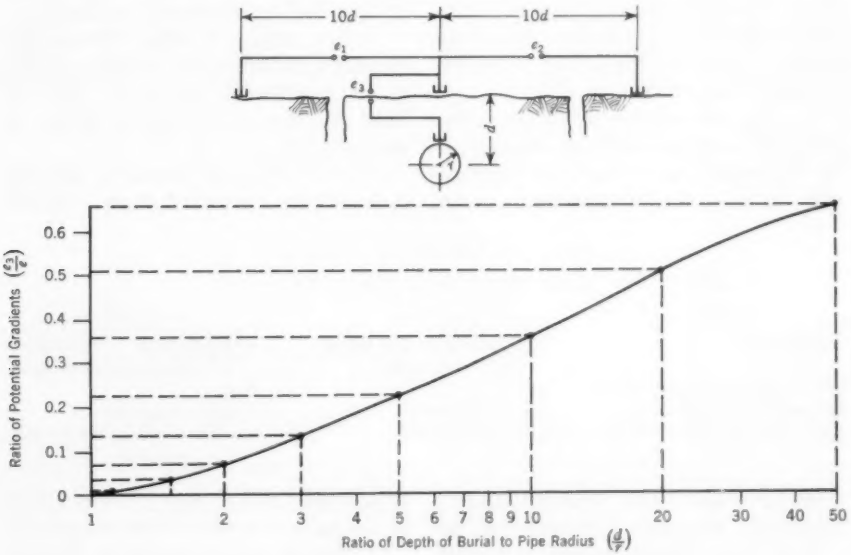


Fig. 2. Relation of Potential Gradients $\frac{e_3}{e}$ to $\frac{d}{r}$

In sectional drawing above, d *is depth of pipe,* r *the pipe radius,* e_3 *the ground-to-pipe potential, and* e *the ground surface potential, as expressed in the following:*

$$e = \frac{e_1 + e_2}{2}$$

$$e_3 = 0.5e\left(\log\frac{d}{r} - \log\frac{2d-r}{d}\right)$$

Curve below shows relationship of potential gradients to the ratio of depth of burial to pipe radius.

This relationship is based upon the superposition of the image effect upon the potential of the pipe to its environment.

E_s is the pipe-to-reference-electrode potential over pipe at the soil or water surface (mv); ρ is soil resistivity (ohm-cm); d is the depth of burial

(ft); r is the distance (ft) of the assumed reference electrode location (E_r) from the center axis of the pipe; and I is the protective current (ma) per linear foot of pipe.

The accuracy with which the subsurface potential can be calculated is limited by the uniformity of the soil and the reliability of the data used. These approximations become more valid as the ratio of d/r increases.

Remote, ground surface, and close-to-pipe-surface potentials approach one another if either the soil resistivity or the protective-current requirement is low. (This is because the development of a resistive coating on the pipe surface, or polarization, is readily achieved.) The effect of shielding by other pipelines and the potential gradient of the protective anode system must be considered when use is made of Eq. 1 and Eq. 2.

The relationship between the potential gradients e_3 (ground-to-pipe) and e (normal to the pipeline) are shown in Fig. 2. This ratio is valid only for uniform pipe surface conductivity and uniform soils. It is helpful in judging the meaning of a pipe potential measurement made to a reference electrode positioned on the ground surface over the pipeline. Thus, if e is 200 mv and ρ is 10,000 ohm-cm, then:

$$I = \frac{42 \times 200}{10{,}000} = 0.84,$$

that is, the pipeline receives 0.84 ma per linear foot. Or, to take another example, suppose that: d is 30 in.; r is 3 in.; E_s is -850 mv; e is 200 mv; $\frac{d}{r}$ is 10; and $\frac{e_3}{e}$ is 0.36 (*see* Fig. 2).

Then, the potential of the pipe to a reference electrode at its surface (E_r) is as follows:

$$\begin{aligned} E_r &= -1{,}000 + 0.36 \times 200 \\ &= -850 + 72 \\ &= -778 \text{ mv.} \end{aligned}$$

Summary

There are two classifications of corrosion current flow in water distribution systems: [1] stray currents, which cause corrosion; and [2] galvanic currents, which are the result of the corrosion process.

The effects of stray current may be minimized or even converted into a protective effect by the following methods:

1. Locate and eliminate the cause of stray current.

2. Tie the distribution system together into a continuous metallic network and return the stray current collected on the system to the negative bus of the d-c power source. This results in a protective effect on the distribution piping.

3. Superimpose galvanic or impressed current to oppose harmful stray-current effects.

4. Isolate the piping into short lengths to minimize the effects of earth stray-current potential gradients. This practice has two disadvantages: [*a*] steep earth potential gradients may cause appreciable metal loss on one end of each pipe length; and [*b*] in order to apply cathodic protection, the joints must be excavated for galvanic-anode connection or for bonding.

Water distribution system operators have not been adequately concerned with harmful stray current effects from cathodic-protection systems applied to gas and oil transmission and distribution systems.

Nonuniformities on buried iron pipe surfaces cause galvanic-corrosion cells

more severe than those caused by dissimilar-metal couples. The open-circuit potential between iron (airfree) and mill or rust scale (magnetic iron oxide) approaches 1 v.

Local-cell pits having short lines of corrosion current flow are not discernible by ground surface potential measurement and are the most difficult to stop.

The best practice to control galvanic corrosion in a water distribution system is to apply a reinforced coal-tar enamel coating and cathodic protection to prevent corrosion at the coating flaws.

The following generalizations for establishing the effectiveness of cathodic protection on bare pipe have support:

1. Long-line corrosion currents are controlled when the protective potential (-0.85 v) is measured to a copper sulfate reference electrode in a remote location (100 ft or further from the pipeline). Intermediate and local-cell corrosion currents are reduced.

2. Long-line and intermediate corrosion currents are controlled when the protective potential is measured to a reference electrode placed over the pipeline. Local-cell corrosion currents are reduced.

3. Long-line, intermediate, and local-cell corrosion currents are controlled when the protective potential is measured close to the pipe surface.

The calculation of potential close to the pipe surface from ground surface measurements using Eq 1 is useful in determining the protective effect without the problem of always positioning the reference electrode close to the pipe surface.

References

1. Pearson, J. M. Electrical Instruments and Measurements in Solution of Electrolysis Problems. Paper presented at the Corrosion Conf., National Bureau of Standards, Washington, D.C. (1937).
2. Correlating Committee on Cathodic Protection. Technical Practices in Cathodic Protection. *Jour. AWWA*, **43**:883 (Nov. 1951).
3. Uhlig, Herbert H., ed. *Corrosion Handbook*. John Wiley & Sons, New York (1948).
4. Belassai, S. J. Induced Alternating Current Used for Cathodic Protection of a Coated Pipeline. *Corrosion*, **12**:1:17 (1956).
5. LaQue, F. L. International Nickel Co., New York. Private communication (1955).
6. Sudrabin, Leon P. An Anomaly in Pipeline Corrosion Diagnosis. *Corrosion*, **12**:99 (1956).
7. Sudrabin, Leon P. A Study of Protective Criteria on a Pipe Section in a Uniform Environment. *Corrosion*, **12**:60 (1956).
8. Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe (Sizes 30 in. and Over)—AWWA C203. Am. Wtr. Wks. Assn., New York (1951).
9. Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe (Sizes up to 30 in.)—AWWA C204. Am. Wtr. Wks. Assn., New York (1951).
10. Burns, R. M. Preservation of the Metallic State. *J. Electrochem. Soc.*, **101**:93C (1954).
11. Schwerdtfeger, W. J. & McDorman, J. J. Potential and Current Requirements for the Cathodic Protection of Steel in Soils. *Natl. Bur. Standards News Bul.*, **47**:104 (1951).
12. Brown, R. H. & Mears, R. B. *Trans. Electrochem. Soc.*, **81**:455 (1942).
13. Sudrabin, Leon P. Some Observations of Cathodic Protection Criteria in Localized Pulling. *Corrosion*, **10**:232 (1954).
14. Howell, R. P. Potential Measurements in Cathodic Protection. *Corrosion*, **8**:300 (1952).

Financing Suburban Extensions

Vance F. Rigling

A revision of a paper presented on Oct. 28, 1955, at the Chesapeake Section Meeting, Washington, D.C., by Vance F. Rigling, Gen. Mgr., General Waterworks Corp., Philadelphia, Pa.

WATER utilities are currently experiencing a crucial test as to their capacity for economic survival—the test of financing an expansion of plant and system at a rate far in excess of the expectations of most water operators.

Basically, this is a result of the increased and improved housing made possible through the easy lending policies endorsed by the federal government and private banking interests. The FHA and GI loans, slum clearance programs, and many other factors have made low-cost loans with very small down payments available to an increasing number of people. This has resulted in the home- and apartment-building boom which the water companies are called upon to serve.

Ironically, no helping hand has been extended to the water works industry, which is left to seek the necessary financing from private capital. Although the federal government established the Rural Electrification Administration to help offset the costs encountered when farm areas and small remote communities stormed electric and telephone companies for these modern improvements, the far larger problem of furnishing the only utility essential to life—water—has not been given any consideration thus far.

It is possible to observe certain general trends in the economic situation presently facing water works owners:

1. Water utilities are called upon to expand plants and to extend mains and services for distances which cannot be afforded at today's rates and expenses.

2. Increasing labor costs and expenses without satisfactory means of adjusting rates to keep pace have resulted in inadequate incomes and low rates of return, which are not attractive to investors.

3. Distribution systems have been expanded to still the demands of the public until, today, the water works need expensive new transmission and feeder main facilities—nonrevenue-producing—to be financed at company expense.

4. Regulation of utility rates has become so strict in most states that there is no latitude to offset any of the above expenses, even partially, without a full-scale rate case with the burden of proof on the utility. This is a very costly procedure.

5. Greater demands for water, brought about by additional consumers and more uses for the product, are countered by dwindling underground and surface sources.

6. A better educated public has demanded a better water without demonstrating a willingness to pay more for the product.

In today's accepted practice in serving suburban developments, only the first three of the above generalities are of interest; nevertheless, because of

their influence upon the general problem of financing, it would be foolish to disregard the others.

Expansion

Developers and contractors were quick to capitalize on the demand for housing, and construction men flooded the water offices with plans for large-scale projects, involving both individual and multiple units. They bought undeveloped ground surrounding established communities to reap a profit in the low-cost lots and to hold construction costs to a minimum, underselling competitors. Residential financing requirements made it necessary to install sidewalks, curbing, streets, and utilities, including water, gas, electricity, telephones, and transportation. The loans made through FHA, the GI bill, and other agencies were proportioned to cover these essentials, and for once it became apparent to the general public that supplying water was a very costly service.

Water works management, engineering, and financing personnel worked up estimates for extending water to the respective developments and, almost without exception, found that applying anticipated revenue against the probable increased expense would not provide the interest on borrowed capital necessary to handle the large projects. This resulted in impossible financing for the water company, so the only alternative was to ask the developers to aid construction with advances either as outright contribution or refundable deposits. This type of cooperation, to the extent needed for present suburban development, was practically unheard of, but it was the only method by which the cost could be directed to the proper individual—the new property owner.

Guaranteed Revenue

Regulatory commissions insist that utilities file annual reports which show the various elements of company business for the year. These reports must include balance sheet and income statement, as well as information on financing, capital additions, and other pertinent subjects. Through such knowledge the commissions hope to control the utility and protect the present consumers from such effects as overcapitalization and absentee management, which might result in increased rates. If unreasonable extensions were made in suburban areas, the rate of return would diminish correspondingly, only to be supplemented later by a rate increase for customers. Therefore, it is altogether proper that each extension stand on its own merits if it is to avoid commission criticism and possible penalty when rates become the topic.

Revenue Multiples

Suburban development hits the more densely populated areas first, areas directly related to established industries called upon for increased production. One of the Atlantic Seaboard states realized the extension problem at the outset and developed legislation controlling water company and developer relations. The regulations provided that the water company was not required to extend its mains in excess of a cost limit estimated to be equal to $3\frac{1}{2}$ times the revenue derived from attached consumers during the first year, and that the rest of the capital would have to be furnished by the developer. Sometimes the developer advanced the full cost of the extension and received refunds as the consumers were attached to the mains; at other times, credit was allowed the developer for houses far

enough along in construction to insure completion.

This initial step in state control was in the right direction because it obligated the water company to extend a dollar amount more commensurate with its capitalized earnings. The multiplier, because of its reasonableness, was apparently determined from the average water works revenue and expense. Such a fixed rule does not take into consideration any economic trends, of course, nor does it give a well managed company having high production and operating costs an even break, less of its revenue dollar being available for capitalization. Much thought must have gone into its preparation, however, because the reasonable pattern it established has remained substantially as written. For one thing, rate increases are automatically compensated for, which is a desirable feature. Because of state control, also, the informal complaints on main extensions became non-existent, as the treatment was considered reasonable and indiscriminate when individual cases were brought to the state. The general result of the state control was that the water company was allowed to design its system according to good hydraulic engineering and could consider future requirements to some degree, but, if the developer felt that he was being penalized for the good of others, he had the right to an informal hearing before the commission which usually resulted in an adjustment of costs.

Incremental Costs

Some public service commissions have chosen to review each extension case with respect to the water companies' operating picture. Expenses, maintenance, depreciation, taxes, and other items are worked up on a per consumer and per mile basis for the specific extension and then applied against the estimated revenue to arrive at earnings suitable for capitalization. The resulting figure is the limit of the utility's responsibility in the extension, and any difference between the amount and the estimated cost must be carried by the developer. This method seems to be the fairest approach to the problem, in that the major elements are considered, but it necessitates a computation for each company, probably on an annual basis.

Operating Ratio

Some water companies have attempted to substitute their operating ratio for the incremental costs of operation and maintenance referred to above. Such companies then deduct depreciation and taxes, and afterwards develop the earnings for capitalizing at the accepted percentage of return. This method of computation is difficult to support before a commission, and has been disregarded in favor of incremental costs. Although it is approximately correct in short extensions, in large extensions excessive operations and maintenance are computed against actual experiences later, so that commissions hesitate to approve the methods.

Tariff Rule

Many obsolete water utility tariffs incorporate in their regulations an extension rule under which the company has been laboring for many years. This dictates that a certain footage of main must be installed for each new consumer or fire hydrant. The footages were established 30–50 years ago and were the result of franchise negotiations made at a period of low costs

and without regard to the companies' ability to pay.

Later, the water management realized they were losing money on extensions and attempted to counter the regulation by adopting a smaller-main policy, but this soon resulted in an inadequate distribution system, not only for fire protection, but in regard to further expansion. Practically all water works incorporate some part of this false design for which they are now making costly replacements and parallel lines.

If a company is faced with this condemning factor in present-day suburban development, it should analyze construction costs and earnings, and petition the state commission for a revision in the tariff regulation. If a water works company is prepared to support its contention, there is little doubt that it will receive real consideration.

Return on Investment

Water companies and public utility commissions are in opposite camps regarding the proper rate of return which should be allowed on an extension. The tendency has been to hold the water works to a top limit of 6 per cent on extensions, with no consideration for a reserve to expand the supply, plant, and transmission lines as the demand approaches peak ability to supply. Thus it becomes necessary periodically to thrust additional burdens on the old and existing customers by virtue of a rate case to provide sufficient plant and appurtenances to meet the demand arising from the system expansion. As long as the public will stand for this treatment, there will probably never be a change in the rate of return allowed, but the 6 per cent limit is definitely too low. Frequently, 6 per cent does not cover the cost of capital.

There are extension cases in the commissions and courts wherein water companies have been directed to install water facilities at little or no rate of return, but these are in the minority, and usually result from a disregard of reasonableness and a placing of too much weight on potential customers who may never attach. If such were the pattern, the result would be confiscatory.

Many bonds at about a 4 per cent rate are sold and this approximates the lower limit usually used by public authorities and water works. Obviously, if many extensions are made at this low limit, rate increases are necessitated at shorter intervals to make up the mounting deficit. Only a limited amount of capitalization is possible through bonds before the utility is called upon to place more equity in the company. Such equity derives rates well in excess of 6 per cent, so the minimum should be above 5 per cent, and 6 per cent is probably best.

Public Relations

Most suburban developments are sponsored by contractors who are good businessmen and, if the water works managers will take the time to show the economics of the proposed extensions, the negotiating parties should usually reach an amicable refundable agreement. The utility officials should not be arbitrary and difficult in stressing company policy as long as the end results—namely, the rate of return—is acceptable.

Contractors' arguments that estimated costs are exorbitant or that installation is too slow should be countered by extending the contractors the right to install the lines under the water company's specifications and supervision. If the contractors can

secure better prices or equivalent material, they should be allowed to do so.

If the developer has limited capital and thus is interested in avoiding the need to furnish the entire cost, the water company can give him credit for all those houses under construction which have advanced to the point where completion is assured. This is guaranteed revenue, which is the ultimate goal, and the developer should only be required to furnish the portion unsupported. The interested party might like to make an outright contribution of the ditching and backfill, in which case the water company could accept a lower rate of return in appreciation of the gesture.

Another cooperative point is to split the deposit aiding construction into two payments, the first due when the material is ordered and the second payable when the actual installation is started.

One large water operator has deducted the cost of meter and service from the refunding amount to reduce the developer's advance, the installation being made if and when necessary. This has the advantage that the services and meters are usually located more appropriately to the premises than if set at the time the mains are installed, which is probably prior to foundation work.

Many businessmen prefer a flat refund in their refundable contracts for each attaching consumer, because the amount is definite and can be considered in their costs. This can be based on the average revenue from existing domestic customers and should not involve estimates of anticipated revenue from higher-class homes, as it only introduces argument. Flat refunds are usually paid at the inauguration of service to the premise, rather than at the end of a year's revenue experience.

The water company should advance information on the value of fire protection to developers. This is an excellent sales point for the contractors because it means lowest insurance rates for their prospective buyers. As a rule, the hydrant revenue warrants the installation of the unit at no extra cost to the developer. The payment of the rental, of course, must be worked out with the city or township to establish responsibility.

Conclusion

It is recommended that the water company establish a main extension policy wherein the company installs construction proportionate to its earnings without speculating on the revenue. The company should then approach the developer or interested parties for the additional requirements, either as refundable deposit or in some form of outright contribution.

Disinfection of Drinking Water With Ozone

Victor A. Hann

A contribution to the Journal by Victor A. Hann, Exec. Vice-Pres., The Welsbach Corp., Philadelphia, Pa.

OZONE is one of the two most potent and effective germicides used in water treatment. Only free residual chlorine can approximate it in germicidal power. The use of ozone for disinfection of municipal drinking water actually antedates chlorination.

Although several of the approximately 200 municipal plants in Europe which use ozone as a disinfectant have been employing it continuously for more than 50 years, many water specialists are not familiar with its germicidal properties nor with its application to water for this purpose.

The dominance of chlorine as a water disinfectant in the United States results from its effectiveness, its economy, and the American practice of carrying residual germicide through the distribution system. Ozone is relatively inexpensive, but not as cheap as chlorine (although improvements in taste, odor, and color resulting from ozone purification will often more than offset the slight difference in cost). What ozone will not do is persist as a residual germicide; in water it rapidly decomposes to ordinary oxygen.

The purpose of this article is to collect and review information on the germicidal properties of ozone and techniques for applying ozone to water.

European Experience

The earliest investigations of ozone for municipal water treatment took place in the last decade of the 19th century. Ohlmuller (*1*) showed that ozone killed typhoid and cholera bacteria and the very resistant anthrax spore. Van Ermengen (*2*) made a comprehensive investigation of the bactericidal action of ozone and found that even the very resistant sporulating types of bacteria were destroyed. Calmette and Roux (*3*) found that all pathogenic and saprophytic microbes encountered in water were destroyed by ozone.

In 1933, Roux (*4*), as president of the Scientific Commission for the Study and Supervision of Water Purification for the City of Paris, announced that it was the unanimous opinion of the commission that ozone was the best method of water sterilization actually known.

In 1937, de Lipkowski (*5*), in justifying the widespread use of ozone in France, cited the virtual disappearance of typhoid fever and other waterborne diseases in those cities where ozone was used. He also cited daily bacteriological records submitted over many years by these cities to the French Supreme Council of Public Health.

Lebout (*6, 7*) has presented detailed data on bacteriological experience with ozone in the city of Nice and has given statistics on typhoid and paratyphoid cases showing that of 92 cases in 1948 none was attributed to municipal drinking water.

Whitson (*8*) made a comprehensive study of ozone purification and testified to its bacteriological efficiency.

United States Experience

In the United States, because no public water supply uses ozone as the primary disinfectant, bacteriological data on a plant scale are sparse. In 1935, Ferkinhoff (*9*) stated that *Esch. coli* counts at Hobart, Ind., were, for raw water, 1,000; for filtered water, 8; and for ozonated water, 0. Chlorine was then added to conform to requirements of the Indiana State Board of Health. (The immediate purpose of the ozone had been for removal of color, taste, and odor.)

At Delhi, N.Y., ozone was used for disinfection for a number of years. Cox (*10*), Chief of the Bureau of Water Supply, New York State Board of Health, stated that it was possible to disinfect filtered water adequately when sufficient ozone was added. The Delhi ozone plant was destroyed by a flood in 1935 and not rebuilt.

At Whiting, Ind., where ozone is applied to the raw water prior to coagulation and filtration (for taste and odor reduction), Bartuska (*11*) reported an average reduction in coliform index from a MPN greater than 240 to 7.5, and a reduction in total count on agar at 37°C from 820 to 40.

At Philadelphia, Pa., where ozone is also applied to unfiltered raw water for taste and odor removal, E. L. Bean (*12*) reported reductions of 95 to 99.9 per cent in coliform organisms and 85 to 99.8 per cent in total counts on agar.

In tests run by the city of Philadelphia and The Welsbach Corporation, disinfection of filtered water in a 1-mgd pilot plant was studied. Of 312 consecutive samples taken during a 1-year continuous run, all samples exceeded bacteriological standards of the USPHS (*13*).

Ozone and Chlorine Compared

Smith and Bodkin (*14*) studied the influence of pH in the germicidal action of ozone and chlorine. They reported less influence of pH with ozone than with chlorine and much lower residuals of ozone than chlorine for equally rapid kill.

Leiguarda, Peso, and de Palazzolo (*15*) made a careful study of the bactericidal action of ozone on coliform bacteria and enteric pathogens, employing the technique used by Butterfield and associates (*16*) in their work on the action of free chlorine. They found the action on *Esch. coli* very rapid and only slightly influenced by temperature (10°–24°C) and pH (6–8). They found action on vegetative forms of *Clostridium perfringens* to be similar to that on *Esch. coli*, but spores were more resistant, requiring higher dosage or longer times for 100 per cent kill. In comparing the action of free chlorine and ozone, they concluded that, part for part, chlorine is slightly more active against vegetative forms of *Clostridium perfringens* but that ozone is more active with the spores.

Bringmann (*17*) investigated the action of ozone and chlorine on *Esch. coli* and found the mode of action to differ: with ozone there is a general oxidation of the cytoplasm, while with chlorine there is a selective injury of vital centers. Part for part, the action of ozone was much more rapid than that of chlorine.

Kessel and associates (*18*) found ozone to be many times more effective than chlorine in inactivating the virus of poliomyelitis. Under their experimental conditions, an identical dilution

of the same strain and pool of virus, when exposed to chlorine in residual amounts of 0.5–1.0 ppm and to ozone in residual amounts of 0.05–0.45 ppm, was inactivated within 2 min by ozone, while 1½–2 hr were required for inactivation by chlorine.

Later, Ridenour and Ingols (*19*) showed that free chlorine was much more effective than combined chlorine in inactivation of the virus of poliomyelitis. Ridenour (*20*) found that an ozone residual of as little as 0.15 ppm inactivated a 1–500 dilution of the virus in as little as 4 min, and as little as 0.1 ppm of ozone residual inactivated the dilution in as little as 20 min. Comparing these data with Ridenour and Ingols' results with free chlorine at a 1–500 dilution, the difference in activity between ozone and free chlorine is much less than reported by Kessel and his coworkers.

Kessel and associates (*21*) also studied the effect of chlorine and ozone on cysts of *Endamoeba histolytica*. A 0.3-ppm ozone residual was several times faster in its germicidal effect than was a 0.5–1.0 ppm dose of chlorine. Newton and Jones (*22*) also studied the effect of ozone on *Endamoeba histolytica* and found it to be highly cysticidal, but made no comparison with chlorine.

In 1952, Lagrange and Rayet (*23*) studied the destruction by various means of the parasitic organism (*Schistosoma mansoni*) which causes the tropical disease bilharziasis. Of several conventional water treatment processes—storage and sedimentation, coagulation and filtration, superchlorination, and ozonation—only the last two resulted in destruction of the organism. A 1-ppm dosage of chlorine produced a 100 per cent kill in 4 min and a 0.9-ppm ozone dosage produced a 100 per cent kill in 3 min. The investigators concluded that ozonation, as normally practiced in the Belgian Congo, would result in destruction of the organism but that ordinary chlorination, as normally practiced, would be unsatisfactory. Mild superchlorination would be sufficient, however.

Proper Application Techniques

It was recognized even by the earliest investigators (*1, 2*) that organic matter in water had an ozone demand which had to be met before ozone became available for germicidal activity. It was also recognized that suspended matter or turbidity in the water made it difficult or impossible to achieve complete disinfection, although substantial reductions in coliform indexes and bacteria counts result from the ozonation of raw turbid waters (*11, 12, 24, 25*).

Once the organic matter in a clear or filtered water has been oxidized and there is an excess of ozone present, the bactericidal action is very rapid. The higher the concentration of ozone, the more rapid is the action. For ordinary disinfection—that is, meeting USPHS standards (*13*)—an ozone residual of 0.1 ppm maintained for 5 min is adequate.

There are two common methods for applying ozone to water. The first is that developed by Otto, in which ozonized air is mixed intimately with water by being drawn into a type of injector (*emulseur*), and an excess of ozone is maintained in the water for 5–6 min in a chamber 15–20 ft deep (column of self-contact). The second method is by dispersion of ozonized air under pressure through porous media at the bottom of a tank 15–20

ft deep designed for a theoretical detention time of 5–10 min.

Control

Control of ozone disinfection is similar to control of chlorine disinfection. The same orthotolidine reagent and comparators used to measure chlorine residuals can be employed to measure ozone residuals (*26*), except that the color should be read immediately rather than after waiting 5 min. While this test is only semiquantitative, it is adequate for control purposes.

It is usually convenient to take a sample of water at the exit of the ozonization chamber. An orthotolidine color corresponding to that for 0.1 ppm of chlorine at this point will assure disinfection.

If quantitative measurement of ozone is desired, simple chemical and photometric methods have been developed (*27*). These tests will provide an accurate measure of ozone residual, and avoid error caused by interference from other oxidants. Continuous measurement of ozone concentration can be obtained by use of commercially available photometers.

Ozone Dosage and Costs

Ozone dosage requirements will depend upon the ozone demand, which in turn depends on water quality. The exact demand can be determined only by an actual test, but the data given in Table 1 can be used as a guide.

Because ozone plants are electrically operated, almost the entire operating cost is electrical. For each pound of ozone produced and applied, 10 kwhr are consumed in large water plants, and perhaps 12–15 kwhr in small ones. Thus, for an ozone dosage of 1 ppm, the electrical cost might range from 75 cents to $2 per 1 mil gal of water treated, depending on plant size and electrical-energy rates. Applying these figures to Table 1, it can be seen that the electrical cost will vary widely, depending upon the water quality, plant size, and energy costs.

TABLE 1

Ozone Dosage Requirements for Various Water Qualities

Water Quality	Approx. Ozone Dosage —*ppm*
Clear, pure ground water	½–1
Treated (filtered) surface water	2–3
Same as above, but from a heavily polluted source	2.5–5
Clear, colored water	3–6

Ozone plants need relatively little operating supervision or maintenance, and no added personnel are required for these services. A generating plant to produce and apply the ozone, however, represents a substantial capital investment. Amortized over the life of the equipment, which is approximately 25 years, this fixed charge will generally amount to about as much as the operating cost.

Iron and Manganese

Iron and manganese salts in reduced oxidation states are colorless and soluble in water. Application of ozone to waters containing such compounds will oxidize the iron or manganese to insoluble oxides which will precipitate. Unless the iron or manganese content is less than about 0.2 ppm, ozone treatment must be followed by filtration to remove the precipitates. Also, special precautions are necessary to measure residual ozone in the presence of manganese and iron salts.

References

1. Ohlmuller. Action of Ozone on Bacteria. *Arb. kaiserl. Gesundh.* (Ger.), **8**:228 (1892).
2. Van Ermengem, E. Sterilization of Waters by Ozone. *Ann. inst. Pasteur* (Fr.), **9**:673 (1895).
3. Calmette, A., et al. The Industrial Sterilization of Potable Waters. *Ann. inst. Pasteur* (Fr.), **13**:344 (1899).
4. Bulletin Municipal Official, Paris, France (Dec. 6, 1932). p. 4722.
5. de Lipkowski, H. Electrical Purification of Drinking Water. *La Technique Sanit. et Munic.* (Fr.), **32**:54 (1937).
6. Annual Report, Nice, France (1941).
7. Lebout, M. The Control of Water Purification at the City of Nice. *La Technique Sanit. et Munic.* (Fr.), **45**:86 (1950).
8. Whitson, M. T. B. Symposium on the Sterilization of Water: (D) Other Processes With Special Reference to Ozone. *J. Inst. Wtr. Engrs.* (Br.), **4**:600 (Nov. 1950).
9. Ferkinoff, T. O. Ozone Solves Color, Odor, and Taste Problem in Hobart Plant. *Am. City,* **50**:47 (Nov. 1935).
10. Cox, C. R. Significant Experiences in the Treatment of Water in New York State. *J. NEWWA,* **53**:444 (Dec. 1939).
11. Bartuska, J. F. Ozonation at Whiting, Ind. *Jour. AWWA,* **33**:2035 (Nov. 1941).
12. Bean, E. L., Prin. Asst. Lab. Engr., Bureau of Water, Philadelphia, Pa. Private communication (Dec. 29, 1950).
13. Drinking Water Standards. *Public Health Repts.* Reprint No. 2440 (Jan. 15, 1943).
14. Smith, W. W. & Bodkin, R. E. Influence of Hydrogen Ion Concentration on the Bactericidal Action of Ozone and Chlorine. *J. Bacteriol.,* **47**:445 (1944).
15. Leiguarda, R. H.; Peso, O. A.; & de Palazzola, A. The Bactericidal Action of Ozone. *Anales assoc. quim. Argentina* (Arg.), **97**:185:165 (1949).
16. Butterfield, C. T. et al. Influence of pH and Temperature on the Survival of Coliforms and Enteric Pathogens When Exposed to Chlorine. *Public Health Repts.,* **58**:1837 (1943).
17. Bringmann, G. Determination of the Lethal Activity of Chlorine and Ozone on *Escherichia Coli. Z. Hyg. Infektionskrankh.* (Ger.), **139**:130 (1954).
18. Kessel, J. F. et al. Comparison of Chlorine and Ozone as Viricidal Agents of Poliomyelitis Virus. *Proc. Soc. Exptl. Biol. Med.,* **53**:71 (1943).
19. Ridenour, G. M. & Ingols, R. S. Inactivation of Poliomyelitis Virus by "Free" Chlorine. *Am. J. Public Health,* **36**:639 (1946).
20. Ridenour, G. M., Prof., Dept. of Environmental Health, Univ. of Michigan, Ann Arbor, Mich. Private communication (Mar. 18, 1946).
21. Kessel, J. F. et al. The Cysticidal Effects of Chlorine and Ozone on Cysts of *Endamoeba Histolytica,* Together With a Comparative Study of Several Encystment Media. *Am. J. Trop. Med.,* **24**:177 (1944).
22. Newton, W. L. & Jones, M. F. The Effect of Ozone in Water on Cysts of *Endamoeba Histolytica. Am. J. Trop. Med.,* **29**:669 (1949).
23. Lagrange, E. & Rayet, R. One Aspect of the Battle Against Bilharzia. Societe d'Epuration et d'Entreprises, Brussels, Belgium (1952).
24. Powell, Marcus P. et al. Action of Ozone on Tastes and Odors and Coliform Organisms. *Jour. AWWA,* **44**:1144 (Dec. 1952).
25. Dickerman, J. M.; Castraberti, A. O.; & Fuller, J. E. Action of Ozone on Waterborne Bacteria. *J. NEWWA,* **68**:11 (Mar. 1954).
26. *Standard Methods for Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA & FSIWA, New York, N.Y. (10th ed., 1955).
27. *Basic Manual of Applications and Laboratory Ozonization Techniques.* The Welsbach Corp., Philadelphia, Pa. (1956).

Identification of Anionic Synthetic Detergents in Foams and Surface Waters

Aaron A. Rosen, Francis M. Middleton, and Neil W. Taylor

A contribution to the Journal by Aaron A. Rosen, Francis M. Middleton, and Neil W. Taylor, all of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

SYNTHETIC detergents have been implicated in several instances of trouble in the operation of water and sewage treatment plants. These incidents, as well as the general characteristics and effects of synthetic detergents, were extensively reviewed in the report of AWWA Task Group 2661 P in 1954 (*1*).

Because the detergents marketed are preponderantly in the class of anionic surface-active agents (surfactants), investigators of operating problems have most commonly employed the colorimetric or titrimetric procedures for analysis of the agents involved. Although these methods give quantitative information and are highly sensitive, they are subject to both positive and negative interferences. They do not, therefore, establish unequivocally the presence of synthetic surfactants, and disputes have arisen as to the interpretation of such results.

It is necessary to develop an improved analytical procedure which not only will be quantitative but also will establish positively that analytical interference is not being interpreted as detergent material. The authors have applied infrared spectroscopy to the detection of anionic surfactants in water and sewage treatment plant foams and even in finished drinking water. Frequently, the method can also provide identification of the chemical class of surfactant present. Unfortunately, large losses of surfactant are entailed in the operations used for recovery and purification, so that the results obtained cannot provide quantitative information.

Water Treatment Plant Foam

The most spectacular example of interference by detergents in the operation of a water treatment plant occurred in November–December 1953, at Wheeling, W.Va. At the peak of the difficulty the raw water contained 12 ppm of detergent, foam stood 3 ft high on the raw-water settling basins, and a 2-ft blanket of foam covered the Ohio River from shore to shore (a distance of 700 ft) below Dam No. 12 at Wheeling. The effects on the finished tap water were equally pronounced (*2*).

A quantity of the foam at the water plant and on the river was collected in washtubs and allowed to liquefy. During the period, several thousand gallons of the raw water was collected in a tank. Part of this water was pumped through a carbon filter. The carbon filter, a sample of the raw

water, and samples of the liquefied foams were forwarded to the Organic Contaminants Unit laboratory at the Sanitary Engineering Center.

Analysis by the methylene blue procedure indicated that the liquefied foam from the settling basin contained 1,170 ppm of surfactant (calculated as alkyl benzene sulfonate). The sample of tank water, analyzed 30 days after collection, contained 1.4 ppm of surfactant.

Consideration of the properties of common anionic surfactants suggested that they could be concentrated from dilute solutions such as liquefied foam, or even from surface waters, by adsorption on active carbon. It was expected that preliminary elution of the carbon with chloroform would remove extraneous organic materials, and that a subsequent extraction with alcohol (95 per cent ethanol) would recover the surfactant in sufficiently pure form to allow identification by infrared spectroscopy. Sadtler (*3*) had already demonstrated the utility of infrared spectra in the identification of surfactants. The application of these operations clearly established the presence

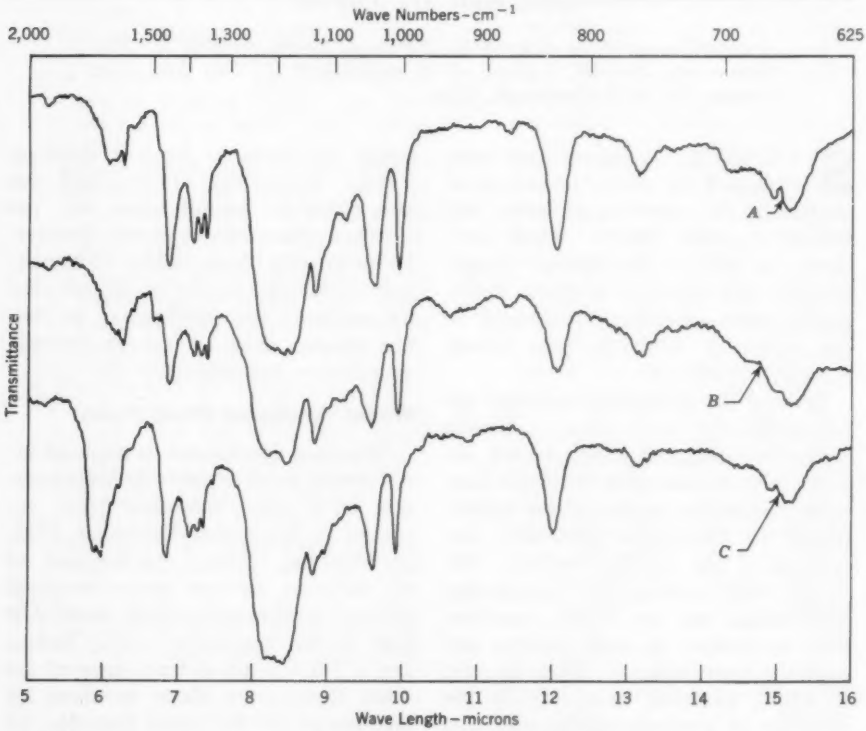


Fig. 1. Infrared Spectra of Liquefied Foams

Spectra of foams from the following sources are shown: A, *Wheeling water works;* B, *sewage works, first city;* C, *sewage works, second city.*

of the alkyl aryl sulfonic acid type of surfactant in the foam. This work is described in reports from the Organic Contaminants Unit laboratory (*4–5*).

The techniques employed, which are described below, were subsequently adapted for use on sewage treatment plant foams and on surface waters.

Activated Carbon—Infrared Method

A 250-ml sample of the condensed foam from the water plant and a similar sample of foam collected at Dam No. 12 were shaken for 30 min with 10 g of activated carbon.* The carbon was filtered off and dried overnight. The filtrate no longer foamed when shaken, indicating essentially complete adsorption of the foaming agent by the carbon. The carbon was extracted for 10 hr with chloroform, then for 8 hr with alcohol. The extracts were evaporated and weighed; the results appear in Table 1. Analysis of the alcohol extracts by the methylene blue method revealed that the extract obtained from the water plant foam was nearly pure surfactant. The extract from the river foam contained approximately 70 per cent surfactant.

The alcoholic extract of the carbon shaken with the water plant foam was prepared as a film on a salt plate, and the infrared spectrum was obtained (*see* Fig. 1). Comparison with the spectra of common anionic surfactants shown in Fig. 2 provides striking identification of the recovered material as an alkyl benzene sulfonic acid salt. Furthermore, the spectrum resembles a surfactant prepared from tetrapropylene benzene more closely than a derivative of keryl benzene. There is no doubt that the Wheeling foam material was composed principally of the alkyl aryl sulfonate type of surfactant.

* Nuchar C-190, a product of the Industrial Chemical Sales Div., West Virginia Pulp and Paper Co., New York, was used.

Sewage Treatment Plant Foam

Samples of liquefied foam from three sewage treatment plants were obtained. These were collected between March and November 1954. Each plant employed an activated-sludge treatment process.

The foams covered a wide range of stability. One sample was collected at a time when the foam was so stable that it formed large windblown balls about the plant grounds. Foam rose out of manholes in the effluent line from the final settling tanks to the river. The sample was collected by placing a bucket beside a manhole and allowing the foam to condense overnight into the bucket. When filtered, it was a straw-colored liquid containing 3,600 ppm of solids, of which 94 per cent was surfactant as found by the methylene blue method.

TABLE 1

Recovery of Organic Extracts From Foam Samples Treated With Carbon

Source of Sample	Chloroform Extract		Alcohol Extract	
	Weight *g*	Concentration* *ppm*	Weight *g*	Concentration* *ppm*
Wheeling water plant	0.059	236	0.224	896
Dam No. 12	0.031	124	0.094	376

* Based on quantity of foam sample.

The liquefied foam was purified in the same manner as the Wheeling foam, by adsorption on active carbon and successive extractions with chloroform and alcohol. The infrared spectrum of the alcohol extract (Fig. 1) clearly showed alkyl aryl sulfonate, resembling very closely the surfactant recovered at Wheeling, which ap-

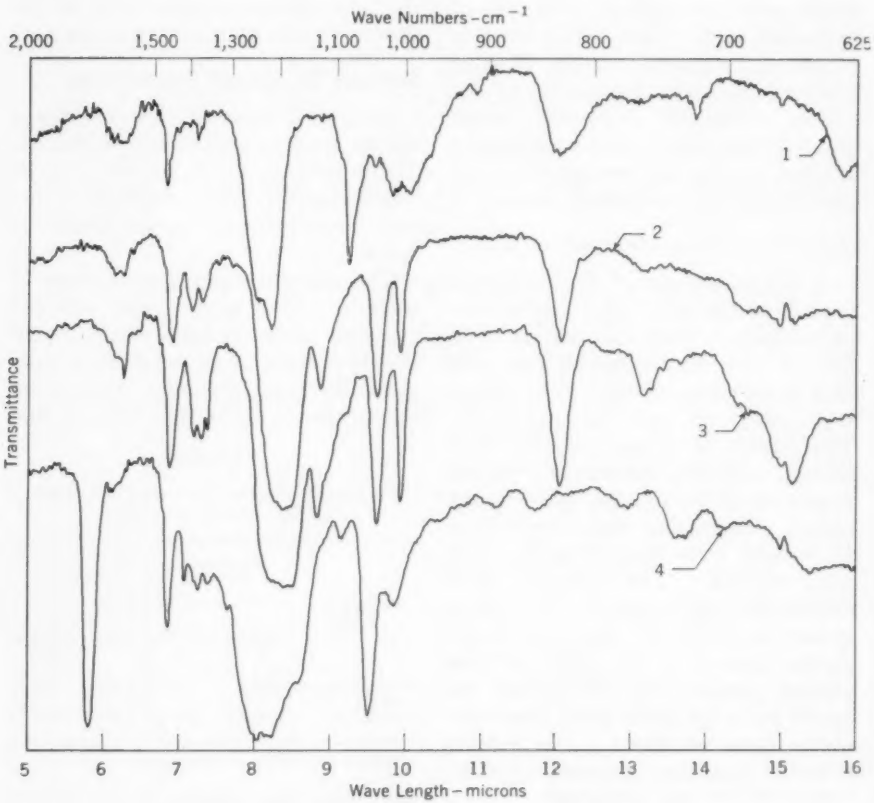


Fig. 2. Infrared Spectra of Anionic Surfactants

Curve numbers refer to the four basic types of surfactants tested, as described on p. 1327.

peared to be a tetrapropylene benzene sulfonic acid.

The foam sample from the second city was much less rich in surfactant. The total recovery of organic matter from the clarified liquid by adsorption on activated carbon amounted to 1,200 ppm, of which the surfactant concentration did not exceed 38 per cent. Nevertheless, the alcohol extract of the carbon contained the surfactant in sufficiently pure form to permit unqualified identification from its infrared spectrum (Fig. 1).

The third sewage plant sample was a foam that had been broken with kerosene; it consisted of grit, grease, wax, and liquid. The usual process of filtration, adsorption, and elution resulted in a few drops of oily material whose infrared spectrum could not be identified as surfactant. The major bands of an alkyl benzene sulfonate were present, but rather indistinctly.

Surface Waters

During the Wheeling foam incident, raw water containing at least 1.4 ppm of anionic surfactant was passed through a carbon filter. The dried carbon was extracted in the usual manner, but surfactant could not be recognized from the infrared spectrum of the alcohol extract. The characteristics were obscured by the strong infrared absorption of other organic substances recovered from the raw water. In order to detect the small quantities of surfactants in surface or tap waters, separation from the bulk of other alcohol-extractable organics must be accomplished.

The desired separation can be carried out by complexing the anionic surfactant in the carbon filter extract with a cationic surfactant. The complex thus formed can be extracted from water with organic solvents (*6, 7*). Most of the other components in the alcohol extracts are soluble in water or alcohol, but only slightly soluble in hydrocarbons and chlorinated hydrocarbons. The extracted complex is identified by its infrared spectrum, in which the characteristics of the anionic surfactant are scarcely altered (*see* Fig. 3). It is desirable to use a relatively simple cationic agent for the extraction, to avoid as far as possible the introduction of extraneous bands in the infrared spectrum. Cetyl trimethyl ammonium bromide (CTAB) meets this requirement.

In order to facilitate the separation of solvent layers in the subsequent extraction, it is desirable to add only the equivalent quantity of CTAB, as an excess tends to emulsify the solvents. When extracting a pure anionic surfactant the equivalence point can be detected well enough by the disappearance of foaming tendency. With impure carbon filter extracts containing small proportions of surfactants, however, this indication of the equivalence point cannot be relied upon. For this reason, the two-phase titration method (*8*) was adapted to serve as an isolation procedure.

Complex Formation—Infrared Method

The following example will illustrate the procedure for concentration of traces of anionic surfactants in surface waters. Cincinnati tap water was filtered through activated carbon to collect organic contaminants. The carbon yielded an amount of chloroform extract equivalent to 124 parts per billion (ppb) of the water. The alcohol extract, equal to 264 ppb of the water, contained 13 per cent surfactant (dodecyl benzene sulfonate) as found by the methylene blue method and 10.7 per cent by the methyl green method (*9*).

One-half gram of the alcohol extract was dissolved in two 5-ml portions of hot alcohol and dispersed in 500 ml of distilled water in a 1-liter separatory funnel, forming a cloudy emulsion. The mixture was extracted with 50 ml of chloroform, which was discarded. A 100-ml portion of the aqueous sample was withdrawn and saved. To the funnel were added 75 ml of chloroform, 2 drops of 1 per cent bromphenol blue solution, 4 drops of 85 per cent phosphoric acid, and sufficient saturated sodium bicarbonate solution to restore the alkaline color of the indicator and provide 1 ml excess.

The sample was reacted with small increment of a standard CTAB solution (200 ppm) until a blue color appeared in the chloroform layer. With standard surfactant solutions, a color change from purple to blue occurs in

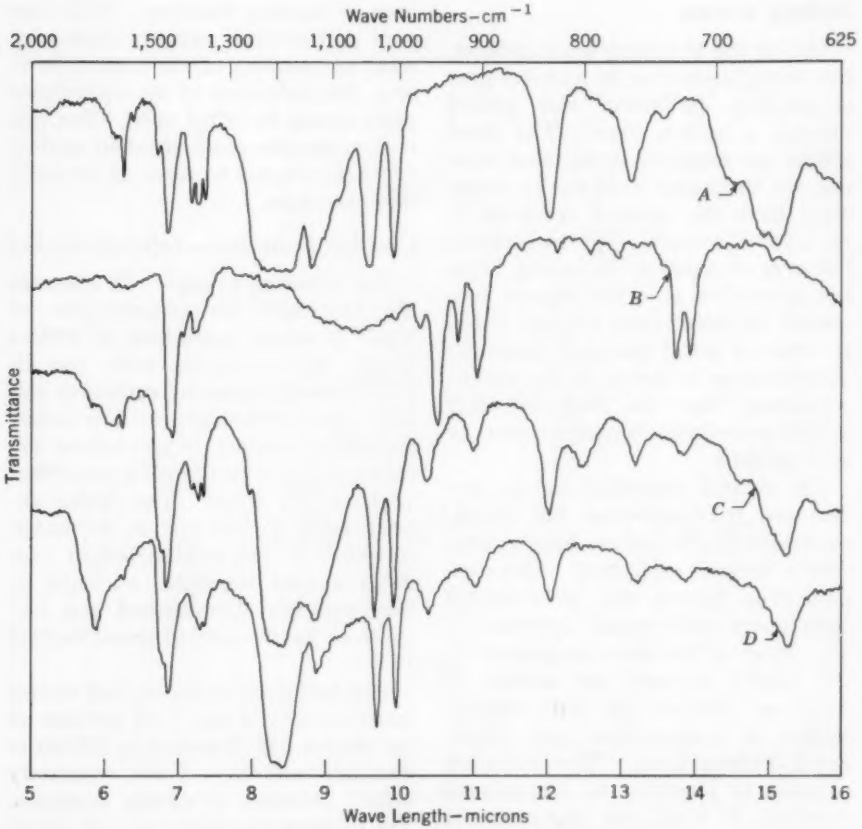


Fig. 3. Identification of Surfactant-CTAB Complexes

The following spectra are shown: A, *Type 3, surfactant;* B, *CTAB;* C, *Type 3 surfactant–CTAB complex;* D, *surfactant–CTAB complex from tap water.*

the water layer immediately before the blue color is perceived in the organic solvent. With the turbid sample from tap water, however, after the color change in the water was observed, an additional 20-ml quantity of the CTAB solution had to be added before the chloroform layer was colored.

The 100-ml portion of the sample set aside was now returned to the funnel and the mixture was shaken thoroughly to react with any excess CTAB present. Most of the dye in the solvent layer was thus reextracted into the water. A trace remaining in the chloroform did not interfere with the analysis. The solvent layer was washed with water, dried over anhydrous sodium sulfate, and evaporated to a volume of 2 ml. From this solution, samples were prepared for infrared spectroscopy in four ways:

1. Dissolved in chloroform
2. Dissolved in carbon disulfide
3. Deposited on powdered potassium bromide by evaporation of its solution and pressed into a disc.
4. Deposited as a film on a salt plate by evaporation of its solution.

The last method was the most practical in terms of experimental facility and amount of information provided by the spectrum. The surfactant-CTAB complex recovered from Cincinnati tap water is clearly identifiable as an alkyl aryl sulfonic acid type from the spectrum shown in Fig. 3.

Experimental Background

Although the various procedures described above were applied successfully to a number of foam and water samples, it was desirable to evaluate the quantitative effectiveness of the procedures and the relationship of operating variables and surfactant types on the results obtained. For these studies, four surfactants, representing the most common anionic types, were employed:

Type 1. Sodium alkyl sulfate (sodium lauryl sulfate)

Type 2. Dodecyl benzene sulfonic acid sodium salt (a keryl benzene sulfonic acid type)*

Type 3. Dodecyl benzene sulfonic acid sodium salt (believed to be a tetrapropylene benzene sulfonic acid type, mixed with inorganic salts).†

Type 4. Dioctyl sodium sulfosuccinate ‡

* Santomerse 3, a product of Monsanto Chemical Co., St. Louis, Mo., was used.

† Conoco DD 40, a product of Continental Oil Co., New York, was used.

‡ Aerosol OT, a product of American Cyanamid Co., New York, was used.

Carbon Adsorption

Stock solutions containing approximately 10 ppm (active ingredients) of each of the four types of anionic surfactant were prepared. Eight liters of each stock solution was permitted to flow upward through a carbon filter at a rate of 8–18 ml per minute. The filters contained 12 g of dry unground activated carbon, previously extracted with chloroform and ethanol, packed lightly to a height of 22–25 cm in a glass tube of 19-mm ID. The effluent was collected in two 4-liter fractions, which were analyzed for surfactant, then discarded. At the end of the run, the carbon was removed from the filter and dried.

The adsorption efficiencies were 98.1–100 per cent. The results are detailed in Table 2.

Elution of Surfactants

The dried carbon was extracted with chloroform for 6 hr in a Soxhlet apparatus. The carbon was vacuum-dried to remove most of the chloroform, then it was reextracted for 6 hr with 95 per cent alcohol. The extracts were recovered from the solvents, dissolved in water, and aliquots were analyzed for anionic surfactant by the methyl green method. The surfactant in the chloroform extracts amounted to only 0.01–0.2 per cent of the amount used; the alcohol extracts contained 15–28 per cent of the original quantity of surfactant. The experimental data on adsorption and elution of surfactants are assembled in Table 2.

The low recoveries raise the question whether the unrecovered surfactant is irreversibly bound to the carbon or whether the incomplete extraction is caused merely by an unfavorable adsorption isotherm. To provide further

TABLE 2

Experimental Data on Adsorption and Elution of Four Common Anionic Surfactants *

Type 1

8 liters	→ Carbon	+ 4 liters effluent	+ 4 liters effluent
9.0 ppm	100%	0 ppm	0 ppm
72.0 mg	adsorbed	0 mg	0 mg
		0%	0%

successive extraction

Chloroform	Ethanol	not extracted
0.02 mg	19.0 mg	53.0 mg
0.03%	26.4%	73.6%

Type 2

8 liters	→ Carbon	+ 4 liters effluent	+ 4 liters effluent
10.1 ppm	100%	0 ppm	0 ppm
80.8 mg	adsorbed	0 mg	0 mg
		0%	0%

successive extraction

Chloroform	Ethanol	not extracted
0.17 mg	17.2 mg	63.4 mg
0.21%	21.3%	78.5%

Type 3

8 liters	→ Carbon	+ 4 liters effluent	+ 4 liters effluent
8.9 ppm	99.7%	0 ppm	0.06 ppm
71.2 mg	adsorbed	0 mg	0.24 mg
		0%	0.34%

successive extraction

Chloroform	Ethanol	not extracted
0.008 mg	20.2 mg	51.0 mg
0.011%	28.4%	71.6%

Type 4 †

8 liters	→ Carbon	+ 4 liters effluent	+ 4 liters effluent
14.7 ppm	98.15%	0.35 ppm	0.19 ppm
117 mg	adsorbed	1.4 mg	0.76 mg
		1.2%	0.65%

successive extraction

Chloroform	Ethanol	not extracted
0.07 mg	17.6 mg	99.3 mg
0.06%	15.0%	84.9%

* Surfactants used were of the following types: Type 1, sodium alkyl sulfate (sodium lauryl sulfate); Type 2, dodecyl benzene sulfonic acid sodium salt (a keryl benzene sulfonic acid type); Type 3, dodecyl benzene sulfonic acid sodium salt (believed to be a tetrapropylene benzene sulfonic acid type, mixed with inorganic salts); Type 4, dioctyl sodium sulfosuccinate.

† The analysis of this stock solution indicated a greater quantity of surfactant than was actually weighed out. It appears that the equivalent weight of this sample in the combination with methyl green is less than the theoretical value.

information on this point, the carbon remaining after the extraction of Type 4 with alcohol (recovery 15 per cent) was extracted for 7 hr with a second lot of alcohol. This time 8.2 per cent of the surfactant was extracted, accounting altogether for 25.1 per cent of the original quantity. These results indicate that the low recovery of surfactant with alcohol is caused by slow extraction due to an unfavorable adsorption isotherm. Alcohol, therefore, can recover a portion of the adsorbed surfactant for infrared identification, but the recovery is much too incomplete to yield quantitative information. For quantitative purposes, the alcohol extraction would have to be carried out for a much longer period, or a more efficient solvent for extraction would be required.

Infrared Identification

Alcohol solutions of each of the four surfactants were prepared by extracting the solid surfactant sample with hot alcohol, filtering from inorganic solids, and diluting to 0.5 per cent concentration. A volume of solution containing 1.5 mg of surfactant was deposited and dried upon 0.7 g of fine potassium bromide powder, from which a disc was pressed.

The alcoholic solution was then concentrated further and a portion was dried to a film on a salt plate under a heat lamp. Infrared spectra of both types of samples of each surfactant were obtained with a double-beam instrument.

In general, the spectra obtained in both ways were quite similar. The sodium lauryl sulfate crystallized during preparation of the film, causing a poor spectrum as a result of excessive light scattering. The spectrum of the pressed-disc preparation of this sample was much clearer. On the other hand, the pressed disc prepared from Type 4 was excessively cloudy, while the deposited film was very transparent and gave an excellent spectrum. The other two surfactants yielded satisfactory spectra from either type of infrared sample, but the film is preferable because of its ease of preparation. For these reasons, the uppermost spectrum in Fig. 2 was obtained from a pressed disc of sodium lauryl sulfate and the other three spectra are those of deposited films.

The surfactants recovered from the carbon filters were similarly prepared for infrared spectroscopy. The spectra obtained were quite similar to the spectra of the pure surfactants shown in Fig. 2 and readily permitted distinction between surfactant types, although there was evidence of slight decomposition of the sodium lauryl sulfate during the experiment. The spectrum of Type 4 shows predominantly the characteristics of an ester. Since ester-like contaminants occur almost constantly in surface waters, it would be difficult to identify this surfactant except when it is recovered in quite pure form. It is highly unlikely, however, that surfactants of this class will be encountered in water pollution problems.

Surfactant-CTAB Complexes

Approximately 1 liter of each of the stock surfactant solutions used for the carbon adsorption studies was reacted with CTAB solution. The procedure has already been described in connection with the isolation of surfactant from tap water. With the stock solutions, it was convenient to approach the equivalence point more closely than with the tap water extract.

The anhydrous chloroform solution of each surfactant-CTAB complex was evaporated to dryness and the residue dissolved in carbon disulfide. Infra-

red spectra were obtained of the carbon disulfide solution, a film prepared by evaporating the solution on a salt plate, and a disc pressed from potassium bromide on which the solution had been dried. Of these three kinds of infrared samples, the film is preferable because it does not contain extraneous absorption bands and is simple to prepare. The infrared spectra of the CTAB complexes of each class of anionic surfactant except lauryl sulfate resembled closely the spectra of the uncomplexed compounds. An example is shown in Fig. 3.

Certain anomalies were observed in the properties of the lauryl sulfate–CTAB complex. It was insoluble in carbon disulfide and formed a white solid on evaporation of the chloroform solvent. The infrared spectrum of the complex as a film on a salt plate was similar to the spectrum of the original surfactant, yet certain obvious differences were apparent. These anomalies have not been explained but they may be a result of the different type of polar group in this surfactant compared with the other three. Another possible explanation is that the spectral differences arise from the differences in crystallinity.

Summary

By a combination of carbon adsorption and infrared spectroscopy, it was possible to prove that some foams encountered at water and sewage treatment plants consisted principally of anionic surfactants of the alkyl benzene sulfonic acid type. This accomplishment resolved previous doubts about the presence of surfactant, doubts which arose from the unspecific nature of the analytical methods formerly employed. With the addition of a step of complexing with CTAB, the presence of the same class of surfactant in tap water was demonstrated.

The process was applied successfully to four types of anionic surfactants but best results were obtained with the alkyl benzene sulfonic acid class which constitutes the overwhelming bulk of detergent production. The preliminary purification steps yield surfactant sufficiently pure to permit identification of its chemical class. The method does not provide quantitative results.

Acknowledgment is made to R. T. Hyde for valued advice in the preparation of the manuscript.

References

1. Task Group Report. Characteristics and Effects of Synthetic Detergents. *Jour. AWWA*, **46**:751 (Aug. 1954).
2. Todd, A. R. Water Purification Upset Seriously by Detergents. *Wtr. & Sew. Wks.*, **101**:80 (1954).
3. Sadtler, Phillip. Analysis of Synthetic Detergents by Infrared Absorption Technic. *ASTM Bul.*, **190**:51 (1953).
4. Middleton, F. M. A Report on the Occurrence of Excessive Foam at the Wheeling, West Virginia, Water Purification Plant. Environmental Health Center, Cincinnati, Ohio (Feb. 1954).
5. Middleton, F. M.; Rosen, A. A.; & Ruchhoft, C. C. Experience in Studying Organic Taste and Odor Substances in Water, Using Carbon Filter Sampling Methods. Paper presented at the Illinois Section Meeting, AWWA, Chicago, Ill. (Mar. 1954; *unpublished*).
6. Auerbach, M. E. Germicidal Quaternary Ammonium Salts in Dilute Solution. *Ind. Eng. Chem., Anal. Ed.*, **15**:492 (1943).
7. Marron, T. U. & Schifferli, Joseph. Direct Volumetric Determination of the Organic Sulfonate Content of Synthetic Detergents. *Ind. Eng. Chem., Anal. Ed.*, **18**:49 (1946).
8. Barr, T.; Oliver, J.; & Stubbings, W. V. The Determination of Surface-Active Agents in Solution. *J. Soc. Chem. Ind.*, **67**:44 (1948).
9. Moore, W. Allan & Kolbeson, Raymond A. The Determination of Anionic Detergents in Surface Waters and Sewage with Methyl Green. *Anal. Chem.*, **28**:161 (1956).

Experiences With the Tenth Edition of *Standard Methods*

Ray L. Derby

A paper presented on May 9, 1956, at the Diamond Jubilee Conference, St. Louis, Mo., by Ray L. Derby, Prin. San. Engr., Dept. of Water & Power, Los Angeles, Calif.

IT has been approximately a year (at this writing) since the tenth edition of *Standard Methods* was made available (*1*). In the author's opinion that is not enough time for it to be thoroughly studied and put into general use. It will take considerable time for workers in the field to abandon their familiar methods for something new, even when the new methods are proved better. This is a normal situation for there is often considerable resistance to dropping a method that has long seemed perfectly suited to local conditions and requirements, merely because a new standard method has been adopted. It is, however, essential that any laboratory providing analytical information for another laboratory or agency should use a standard method.

Recently, Michael J. Taras, in connection with his work on the Joint Editorial Board for the eleventh edition of *Standard Methods*, sent out a questionnaire to water laboratories in the United States, England, and Canada. This questionnaire requested information on the methods now being used and suggestions for improving these methods, if they were considered unsatisfactory. Analysis of the responses to these questionnaires has indicated several methods that need improvement and suggestions for other methods that should be added to the next edition.

The aluminon method for determining the presence of aluminum in waters is said to have a lack of distinct graduation in standards and poor reproducibility of results. One difficulty arises from the fact that any aluminum present as particulate matter, such as a finely divided floc, is not determined because of the pH of the aluminon solution. This also causes trouble with the fluoride determination, which is carried on in an acid medium, as aluminum in small amounts causes a decrease in the apparent fluoride result.

Some respondents still prefer the hematoxalin method for aluminum, and one reports that a cyanide modification greatly improves the older methods. This should be further studied by the committee.

Several respondents state that the endpoint for the calcium EDTA procedure is elusive and difficult to match on successive titrations or by different analysts. It has been suggested that cresol red indicator be used as a standard for color comparison or that the titration be carried out in a spectrophotometer cell.

Although the selenium determination is performed by only a few laboratories, it is reported as being unsatisfactory by four out of the seven labora-

tories which make this determination. The reasons why the selenium tests are considered unsatisfactory were not specified. Probable causes, however, are the large amounts of water to be evaporated and the difficulty in obtaining reproducible results during the oxidation procedure. A similar situation prevails with the tannin and lignin determinations. None of the complaining laboratories, however, could offer any suggestions for improving these tests. This is not very surprising, for the committees that set up these methods were hard pressed to find the procedure they did.

Current Practice

Taras' questionnaire also revealed the following interesting information:

In addition to the standard carbamate procedures for copper, methods based on dithizone, dithiooxamide malonic acid, potassium xanthogenate, and neocuproine are used by individual laboratories throughout the country. These other nonstandard methods were all investigated by the committee at the time the carbamate method was studied. The committee found the carbamate method the simplest and most accurate used. The fact that many laboratories still use nonstandard methods is an excellent example of the reluctance of many people to abandon familiar methods.

About one-half of the respondents who perform the determination for oil use a nonstandard solvent or method. The solvent finally decided upon as the standard to be used was probably more or less arbitrary, inasmuch as there are very many solvents and a large variety of oils and greases reacting in various degrees with the solvents. More study should probably be given to determine the most satisfactory solvent under all conditions. Again, the fact that many nonstandard methods are still in use shows the reluctance of individuals to change.

Approximately one-third of the respondents employ a colorimetric determination for pH, depending on commercial test kits and comparators for routine control applications. These laboratories also used the standard glass electrode, presumably for check purposes. The glass electrode seems such an easy and accurate method, uninhibited by such interfering substances as color and turbidity, that one wonders why it would not be used in preference to colorimetric methods. One possible explanation may be that routine pH determinations are made with the colorimetric kits by nontechnical personnel.

Nearly one-half of the laboratories determining zinc use such nonstandard methods as sodium diethyldithiocarbamate and potassium ferrocyanide. The same thing may be said about the determination of zinc as was said about the determination of copper.

A trend in the right direction is indicated by the fact that one out of eight respondents use a photoelectric device for turbidity measurements. Many laboratories (about one out of three) use commercially marketed turbidimeters.

New Methods

Several new methods have been suggested by respondents for inclusion in future editions of *Standard Methods*. These are determinations of radioactivity, synthetic detergents, strontium, lithium, and chlorine dioxide. Radioactivity, of course, has been assuming a more important place in water analysis in recent years, and it is believed very desirable to have data on background activity in a given area, and also to be able to determine radio-

activity above this background that might be caused by the disposal of radioactive waste on the watershed or fallout from atomic-weapons testing.

Synthetic detergents are becoming quite important in certain areas, particularly where sewage wastes enter streams which are subsequently used for water supply. The difficulty due to taste and odor and foaming problems caused by synthetic detergents is well known.

Strontium seems to be somewhat important now largely through its connection with radioactivity but also because some analysts wish to separate strontium and calcium. Lithium, which has hitherto been largely included with sodium, may be of interest in connection with potential disposal of radioactive materials. Development of a good method for chlorine dioxide determination is becoming more important with the use of this compound for taste and odor control.

Other determinations which have been suggested are methane, filterability index, uranium, thorium, ozone, mercury, bromide, and DDT. Methane, of course, is of concern in some areas where it is found in well water and has caused several serious explosions. Although the use of DDT as an insecticide is still frowned upon by many public health agencies, it has on many occasions appeared to be the only answer to a rather perplexing problem. A method for determining filterability index would be of use for comparison of treatment methods. Uranium, thorium, and barium are of major interest from a radioactivity standpoint. Barium is also occasionally useful in checking pollution from oilfield brines. A good test for ozone would be highly desirable where ozone is used for taste and odor control. There have been some recorded incidents in which ozone was highly toxic to fish. A satisfactory determination would be of value in such cases, as the amounts concerned have generally been rather small.

It also appears that the tenth edition draft of the chlorine residual section is weak. One reason stems from the fact that Palin's modifications of his ferrous ammonium sulfate titration (*2*) were omitted. A second cause is the brief and cursory reference to the photometric method of determining chlorine residuals which put the important chlorine residual section out of balance with the rest of the book. A suitable draft is now being prepared.

Three new sections are ready for critical scrutiny by the AWWA Standard Methods Committee. These are a direct iodide procedure, a methane procedure, and a photometric method for the determination of free available chlorine residual.

Conclusions

All these developments indicate that the tenth edition of *Standard Methods* is just another rung in the ladder on which to stand while preparing the next rung. Dissatisfaction with current methods prompts us to look for newer and better means. New organic specific reagents are discovered every day; new principles discovered in the fields of physics and chemistry are applied to analytical eqeuipment; and new developments in science and industry require new methods for analyzing their wastes.

The present policy of the Standard Methods Committee is to maintain a continuing study of present methods and search for new methods. This is a big step in the right direction, as many faults in present methods will have been corrected or more satisfactory methods developed by the time

the eleventh edition is scheduled to be published. This will save many last-minute headaches for the committee members and make a more satisfactory publication. All water laboratory workers are urged to maintain close contact with the committee and to report promptly suggestions for new methods or changes in current methods. This is not only an invaluable aid to the committee but directly benefits the laboratory worker himself, in that a more useful tool for the industry is produced.

References

1. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA & FSIWA, New York (10th ed., 1955).
2. PALIN, A. T. Determining Residual Chlorine in Water by Neutral Orthotolidine Method. *Wtr. & Sew. Wks.*, 101:74 (1954).

Discussion

Michael J. Taras

Chairman, AWWA Committee 8930 P—Standard Methods for the Examination of Water, Sewage, and Industrial Wastes; Research San. Chemist, Springwells Filtration Plant, 8300 W. Warren St., Dearborn 1, Mich.

The questionnaire mentioned in Ray Derby's excellent paper was sent during February 1956 to approximately 130 selected laboratories in the United States and abroad. Mailings were made to members of the subcommittees which assisted in the compilation of the tenth edition as well as to other individuals who were believed to have an interest in the improvement of *Standard Methods*. By the end of July 1956, a total of 66 completed questionnaires had been returned. The new Standard Methods Committee would welcome a 100 per cent response and urges those individuals who received a questionnaire to send back the completed forms. Individuals who did not receive a questionnaire and would like to voice a criticism of any of the material in the section devoted to the chemical analysis of water are invited to communicate with the writer at the address above.

No individual, and no group of individuals such as the Joint Editorial Board, is in a position to know all of the virtues and failings of an accepted chemical procedure. Progress is achieved through an exchange of views and a pooling of knowledge.

Comments on newly developed methods as well as improvements of the established procedures are invited. The committee is particularly anxious to make contact with individuals and organizations engaged in the routine or research analysis of water samples. News of any pertinent investigations now under way in these laboratories would be of value.

Derby has ably cited the determinations which require continued attention. Among other methods on which information from personal experience is sought are: the tyrosine method for chlorine dioxide, the neocuproine method for copper, gasometric and combustible-gas indicator methods for methane, distillation and nondistillation methods for iodide, and the ion-exchange and zincon method for zinc. It cannot be emphasized too strongly that the usefulness of the next revision will be enhanced by the disclosure of the deficiencies of the tenth edition.

Algae and Other Interference Organisms in Indiana Water Supplies

C. Mervin Palmer and H. Wallace Poston

A paper presented on Feb. 9, 1956, at the Indiana Section Meeting, Indianapolis, Ind., by C. Mervin Palmer, Research Biologist in Charge, Interference Organisms Studies, and H. Wallace Poston, Sr. San. Engr., both of Water Supply & Water Pollution Program, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

MORE than one-third of the population of Indiana depends, either wholly or in part, upon a surface water supply which is treated and distributed by more than 65 water treatment plants. Of these plants, approximately two-thirds obtain their water supply from rivers and smaller streams, one-third from lakes and impounding reservoirs (*1*).

Lake Michigan is one of the most important of these sources; others include the White, Ohio, and Wabash rivers, as well as such smaller sources as Buck Creek and Center Lake. The following seven cities and towns of Indiana, selected at random, provide good examples of the various surface waters which are being used: Michigan City draws from Lake Michigan; Milan, from an impounding reservoir; Mitchell, from the White River; Montpelier, from the Salamonie River; Mount Vernon, from the Ohio River; Paoli, from Lick Creek; and Warsaw, from Center Lake (*2*).

All these surface water sources contain algae and many other organisms which interfere with water treatment in a number of ways (*3*). These organisms are almost completely absent from ground water. As an increasing number of water utilities are forced to turn to surface water supplies, more and more operators will become involved in the detection and control of plant and animal growths.

Biological Problems

The present discussion is concerned exclusively with problems caused by the growth of various aquatic plants and animals; it does not deal with difficulties resulting from intestinal bacteria, pathogenic organisms, industrial wastes, or turbidity caused by silt. It is realized that there exist certain problems of which the cause is a combination of biological and other factors, or in which biological and nonbiological factors cannot readily be separated.

The more important biological problems include: tastes and odors in water (*4*); reduction of the length of filter runs (*5*); and the presence in the distribution system of growths, worms, midges, bacteria, and other organisms which may be visible in the finished water, cause tastes and odors, clog meter screens, or reduce the flow in the pipes (*6*). Other problems are caused by surface, marginal, and bottom growths in reservoirs or basins, and the effects of plankton and other growths on coagulation, sedimentation, and chlorination. These organisms, clearly, can interfere with or affect almost every phase of the treatment

and distribution process, and they add many complications to the problems of water treatment and service.

Nature of Indiana Waters

The many aquatic plants and animals found in Indiana waters constitute several thousands of species. It is advisable, therefore, to consider them not individually, but, for the most part, by groups. The more important of these groups are as follows: algae (*7*), including diatoms, green algae, blue-green algae, and algal flagellates (*8*); aquatic animals, including nematodes, *Nais* worms, copepods, and rotifers; fungi, including actinomycetes, iron bacteria, molds, and zoogloeal bacteria; and water weeds, including certain sedges, milfoils, pond weeds, and willows. This article discusses primarily the algae, with some references to aquatic animals and fungi.

A brief survey of two lakes and two rivers which are representative of water supply sources in Indiana should help to make evident the particular problems caused by organisms with which treatment plants most frequently must contend. The four bodies of water selected for consideration are Lake Michigan, the White and Ohio rivers, and Lake Maxinkuckee (together with other small lakes and impoundments).

Lake Michigan

Lake Michigan has a great predominance of diatoms over all other algae and all other plankton organisms. The numerous studies which have been made of the lake are all in agreement in this observation (*9–12*). Diatoms generally account for 90 per cent or more of the total plankton count; in some years they have averaged 94 per cent, and in some seasons, 98.8 per cent, of the total plankton count of the lake. This great mass of diatoms is composed primarily of only seven genera, *Synedra, Fragilaria, Tabellaria, Cyclotella, Asterionella, Navicula,* and *Melosira.* Each genus tends to display its own pulse independently at some period. In one year, for example, *Synedra* dominated in May, *Fragilaria* in June, *Tabellaria* in July, and *Asterionella* in November (*13*). *Synedra* has constituted as much as 65 per cent of the total diatom population.

Lake Michigan has a decided dearth of green algae as these organisms constitute only about 1 per cent of the total yearly average of plankton. Only six genera are common: *Closterium, Cosmarium, Sphaerocystis, Dictyosphaerium, Ankistrodesmus,* and *Scenedesmus.*

The blue-green algae are also not prevalent, comprising a yearly average of about 2 per cent of the total plankton. The genera most frequently encountered are *Oscillatoria, Lyngbya, Gomphosphaeria, Anabaena, Chroococcus, Coelosphaerium,* and *Microcystis.*

Algal flagellates are the second most abundant group of plankton in Lake Michigan, comprising an average of about 6 per cent of the total yearly count. *Dinobryon* makes up about half of the flagellate count. *Synura* is the only other common genus: being very fragile it is often destroyed in water samples during the process of concentrating the organisms for counting.

According to Damann (*14*) a total of 363 genera, representing 784 species, of plankton organisms has been reported for Lake Michigan. The species are distributed as follows: 316 diatoms, 182 protozoa, 124 green algae, 67 rotifers, 39 blue-green algae, 37 crustaceans, and 19 others.

Quantitatively, the individual counts may range from about 80 to more than 4,000 organisms per milliliter, while monthly averages may range from approximately 100 to 2,000 per milliliter. At Chicago, the average annual yield for a period of 14 years was 918 organisms per milliliter (*11*).

White River

In contrast to Lake Michigan, the White River tends to have a relatively large population of green algae, while diatoms may range from abundant to sparse. Diatom pulses tend to be limited to late spring and fall (*15, 16*). The most common genera of diatoms include *Synedra, Nitzschia, Cyclotella,* and *Stephanodiscus,* while among the green algae *Scenedesmus* is the most common. *Chlamydomonas* and *Chrysococcus* are two of the algal flagellates frequently encountered (*17*). The blue-green algae tend to be few in number (*18*).

Plankton counts for the White River have ranged from about 50 to over 100,000 organisms per milliliter (*19*). At Indianapolis, Hupp (*20*) reports a semimonthly average ranging from approximately 500 to 20,000 per milliliter over a 4-year period. Plankton counts have been reported in terms of areal standard units for the White River at Anderson and Muncie (*21*). They range from 0 to 2,980 and again indicate that diatoms and green algae may alternate as the dominant forms.

Ohio River

Several striking differences between the Ohio River and its tributaries have been reported (*19*): in the Ohio, green algae are not as numerous; euglenids are notably scarce; diatoms, which comprise the major part of Ohio River plankton, are present in larger numbers than in the tributaries; there is a dearth of summer plankton except immediately below Cincinnati and Louisville; and the plankton peak is in the spring rather than in the summer. In the Ohio River, adjacent to Indiana, the principal diatoms include *Melosira, Synedra, Fragilaria,* and *Asterionella.* The number of plankton organisms per milliliter ranges from about 180 to 1,500.

Little information is available, at the present time, concerning the distribution of actinomycetes in Indiana waters. They have been reported for the Ohio River (*22*) and it is assumed that they may be abundant in the waters of both lakes and rivers.

Other Lakes and Reservoirs

Reservoirs and lakes (other than Lake Michigan) are normally capable of supporting large populations of algae and other organisms in the form of plankton, blooms, and marginal growths. These in turn have increased the magnitude of the organic material which causes trouble in water treatment. Such bodies of water can be used as a water supply only when modern methods for controlling the undesirable forms are practiced (*3*). More than 85 years ago, a committee appointed to investigate the advisability of a new water system for Connersville, Ind., stated (*23*):

> The old-fashioned reservoirs for the accumulation of enormous quantities of stagnant water, as well as for the growth and encouragement of green slime, frogs, tadpoles, water lizards, frog spew, juvenile snapping turtles, crawfish, decomposing cats and puppies, defunct insects, snakes, eels, catfish are a thing of the past.

About 45 years later, however, John N. Hurty, then Secretary of the Indiana Board of Health, stated (*23*):

Evidently the earth in this region is almost exhausted of its waters, and then the surface, and it alone, must be looked to for a supply. This means we must in time build great dams along our streams forming reservoirs for impounding water against the time of need.

Records for Indiana lakes and reservoirs indicate that there are a large number of varieties of plankton organisms which may be present in abundance (*24*), together with the many plants and animals in the shallow margins which can break away and add to the amount of living or dead organic matter dispersed in the water (*25*). All four types of algae are well represented in the lakes and reservoirs, and in addition the Protozoa, Crustacea, sponges, worms, and other groups are abundant (*26–28*). Only a few of the more common genera are listed here. These are, for the diatoms, *Asterionella, Fragilaria, Melosira,* and *Synedra;* for the green algae, *Pediastrum, Scenedesmus, Ankistrodesmus, Coelastrum,* and *Hydrodictyon*; for the blue-green algae, *Anabaena, Aphanizomenon, Microcystis, Coelosphaerium,* and *Lyngbya;* and for the flagellate algae, *Dinobryon, Ceratium, Chlamydomonas, Peridinium,* and *Mallomonas.* The more common microscopic aquatic animals include *Cyclops, Daphnia, Diaptomus,* and nauplii. The tendency for a number of the algae to occur as extensive visible surface blankets or "bloom" is common.

Plankton counts for Indiana lakes and reservoirs vary widely, with the maximum and average numbers, at least for the surface layer of water, being higher than for most of the streams.

Nature of Interferences

The presence of a high proportion of diatoms in the plankton of Lake Michigan, together with the occasional development of certain flagellated algae such as *Dinobryon,* would indicate that treatment plants obtaining their water from this lake could expect frequent reductions in the length of filter runs (caused by the diatoms) and taste and odor problems (caused by certain diatoms as well as by the flagellates).

Available statements from treatment plants make it evident that these problems do exist. Michigan City (*29*) reports that its chief source of tastes and odors is algal growths, or the reaction of chlorine with the organic matter in the raw water. Algae begin to appear in increasing numbers in April or May, depending upon the weather. These are of the filamentous types which do not produce much taste or odor. Later, however, when counts reach 850 or more microorganisms per milliliter, they have taxed the plant's capacity to remove the odors and tastes. The Gary-Hobart plant (*30*) reports that odors in its raw water were predominantly of natural origin, the most common odor being musty.

In 1951 (*31*) the alga, *Dinobryon,* developed in the southern end of Lake Michigan in June and July in numbers sufficient to impart a prominent fishy odor to the water and produce a threshold odor as high as 13. (A threshold odor of 10 is considered high for algal odors in the lake water at Chicago.) A range of 140–700 areal standard units of *Dinobryon* was reported in the raw water at the South District Filtration Plant in Chicago and represented, at times, up to 47 per cent of the total algal count. The fishy odor produced by *Dinobryon* has the reputation of being one which is readily adsorbed by activated carbon. It is estimated that it required $70,500 worth of activated carbon to control for a period of 2 months the odor

caused specifically by this alga. *Dinobryon* reappears almost every year to cause this type of nuisance at Chicago.

Baylis (*5*) reports ten species of diatoms in Lake Michigan at Chicago which may occur in large numbers at any time during the year. *Tabellaria* occurs in greatest abundance most of the time and is considered to be more responsible than any other microorganism for the short filter runs. *Fragilaria* and *Asterionella* are also important in filter clogging. In general, the length of filter runs decreases as the number of microorganisms increases. Representative filter runs in July ranged from 41 hr to 3½ hr, while plankton collected on the filter ranged from 60,500 to 4,572,700 organisms per square inch of sand surface.

White River algae and other organisms tend to vary both in numbers and in kinds much more than those in Lake Michigan. This means that treatment plants using the White River water might expect a correspondingly greater variation in the kinds and frequency of troubles caused by organisms.

Indianapolis (*32*) reports that its most objectionable tastes and odors are caused by the alga, *Synura,* by gas plant wastes, or by heavy rains flushing out barnyards and streams. *Synura* is known to cause a strong cucumber odor and also a distinct bitter taste that remains in the mouth long after the water has been swallowed. The odors which generally accompany heavy rainfall are described as sewage, musty, river, or fishy odors.

One chemist reports that a strong cucumber odor in the White River water was traced to the mouth of a small stream flowing into the river. A concentrated growth of *Synura* was found at that location and destroyed by local application of an algicide. *Synura* is a potent producer of tastes and odors. As few as 5 colonies per milliliter is sufficient to cause trouble. Fortunately, *Synura* is more sensitive to copper sulfate than many of the other flagellate algae.

Achnanthes is one of the diatoms at Indianapolis which was reported by Calvert (*33*) to be resistant to copper sulfate (1 ppm) but sensitive to chlorine (0.25 ppm). In contrast, an unidentified filamentous microorganism withstood chlorine (4 ppm) but was eliminated with copper sulfate (2 ppm). Floating algae formerly were present in the settling basins and had to be skimmed at the outlet until control was obtained by the almost continuous application of copper sulfate and chlorine.

At Indianapolis (*34*) the diatom, *Melosira,* was predominant when filter runs dropped, overnight, from 30 hr to about 2 hr. Total plankton counts in water going to the filters averaged about 7,000 per milliliter. At other times *Cyclotella* has been the diatom troublesome in clogging and in penetrating filters. Various copepods have also been found in the distribution system as a result of the passage of eggs of these organisms through the filter.

Although the Ohio River is reported to have lower plankton counts than its tributaries, water treatment plants using the Ohio River water report troubles from these organisms.

Evansville (*35*) reports the presence of odors "from natural causes" and that the odors were associated with the presence of algae and other material. During the summer months the algae have been sufficiently abundant to require the use of copper sulfate at the entrance of the flume. As long ago as 1913, Evansville (*36*) reported abnormal growths of diatoms

and green algae which clogged the sand and made it difficult to operate the filters for more than 4 hr without washing. In addition, a fishy odor was apparent while the filters were being washed.

New Albany (*37*) reports algal growths in the settling basin which had to be controlled during early summer and late fall and which required the use of copper sulfate and other treatments.

Cincinnati (*38*) has reported short filter runs caused by algae in the river which have, at times, interfered considerably with operating routine. As much as 8.9 per cent of the water pumped during a week has been used for backwashing, making the provision for ample wash water pumping capacity a necessity.

Taste and odor problems at Cincinnati have at times been very severe. Fully 80 per cent of the taste occurrences caused by river conditions may be classed as stagnant, algal tastes, or as ill-defined "melted-ice" or "river" tastes in winter, and, in general, less than 20 per cent of the trouble is of phenolic origin. Actinomycetes have been reported for the Ohio River (*21*) and could be associated with the production of earthy odors.

Cities using water from the smaller lakes or from impoundments report difficulties caused by the plankton. Hobart (*39*) had so much difficulty from tastes and odors caused by algae present in the small lake from which it was supplied that a new source was obtained by combining with Gary to use water from Lake Michigan.

Crabill (*40*) reports periods of high plankton counts in water from Geist Reservoir near Indianapolis.

Valparaiso, which uses water from Flint Lake (*32*), reports taste and odor trouble during the lake "overturn" in the spring and fall and during the periods of abundant algal growth in the summer. During an excessive growth of the protozoan, *Vorticella*, a particularly bitter taste as well as odor was apparent. Algal counts at Valparaiso have exceeded 1,700 units. When free residual chlorination has not been practiced, a green algal slime has developed on the walls of the settling basin and filter troughs during the summer months. In dead ends in the distribution system, white worms have been found. Some of these were identified as the genus *Nais*, which is one of the bristle worms. Tastes have developed through the action of chlorine on organic matter in the mains, which had to be controlled by a systematic flushing program.

Just across the state line, at Champaign-Urbana, Ill. (*41*), various filamentous bacteria and other organisms multiplied in the distribution system to such an extent that they frequently reduced the inside diameter of a ¾-in. pipe to that of a lead pencil. Periodically they sloughed off and caused innumerable complaints from water consumers. Calvert (*42*) reported that in Indianapolis the bacterium, *Microspira desulfuricans*, was common in samples from dead-end mains, while both *Microspira* and encapsulated organisms were common in pipes of the distribution system. He assumed that these bacteria could be of tremendous importance from the standpoint of taste and odor. One of the pigmented bacteria, *Flavobacterium*, has also been found in the distribution system (*43*).

In summary, it is apparent that treatment plants using water from Lake Michigan or from the Ohio River can, in general, expect most of their trouble from diatoms and from flagellate algae which will cause, respect-

ively, filter clogging and taste and odor problems. Treatment plants using water from the White River or other tributaries of the Ohio, and from impounding reservoirs and lakes other than Lake Michigan, can expect a much greater variation in the number and kinds of algae and other organisms, and consequently a greater range in the number and kinds of problems caused by biological growths.

Control of Nuisance Organisms

The problems associated with nuisance organisms and municipal water are difficult because so little is known of the organisms involved or methods of control. In taste and odor problems, the composition of the offending substances is unknown, and they are almost impossible to extract from the water in a pure form.

Articles have been written on biological problems and their solution, but often the conditions described are slightly different from one's own, or facilities for providing comparable treatment measures are not available. The actinomycetes group of organisms is reported by Silvey (*47*) as being a cause of tastes and odors in water supplies of the Southwest, and yet until a few years ago these organisms were not associated with tastes and odors in that area.

Although the problems are difficult, a means of approaching them exists. It is known, for example, that under certain temperature conditions algae will produce a bloom if the nutrients (phosphorus and nitrogen) are available in adequate supply. Sunlight is essential for growth of algae as is carbon dioxide. It is also known that copper sulfate, chlorine, and chlorine dioxide will kill algae, while activated carbon will adsorb odors already formed or prevent the necessary sunlight from reaching the organisms. Chlorine, chlorine dioxide, ozone, or aeration will oxidize many taste and odor compounds.

The water treatment plant is the best possible place to determine the most effective means of controlling nuisance organisms or associated problems. It is true that there may be a lack of adequate personnel to carry out investigations as one would like, especially if the plant is small, but the recurring problem conditions found in individual plants must be overcome, and are hard to reproduce or simulate in the laboratory. Many operators have found it profitable to make studies of specific problems, later incorporating changes based on these studies in their plants. Michigan City, for example, found that decomposition and buildup of sludge was adding to taste and odor problems and decreasing the settling time. The addition of sludge rakes in the existing basins and in a new basin has made it possible to control tastes and odors with a maximum of 40 lb of carbon per million gallons (*29*). The Hammond water works has found that the application of carbon prior to chlorination has made it possible to remove all taste and odors with a minimum cost (*51*).

Indiana water plant personnel have experimented with all types of treatments for taste and odor problems, which are not always due to nuisance organisms. One of the worst problems in the state has been at the Whiting plant, where the Lake Michigan source was polluted with municipal and industrial wastes. In 1947, Besozzi and Vaughn (*52*) made control studies of this problem, using chlorine dioxide, free residual chlorination, chloramine, granular activated carbon, powdered activated carbon, and ozone. The results of these studies, available

in various publications, should be utilized in solving particular plant problems.

It is certain that, when such problems exist, experimentation with various methods of water treatment will make it possible to arrive at the best treatment for each specific case. The addition of a biologist to the laboratory staff will prove both helpful and profitable if problems caused by growth of various organisms are encountered frequently. The biologist would be helpful because of his ability to find, to forecast, and to identify organisms, and profitable because he could prescribe the most economical treatment. Operators of small water works might solicit part-time help from biology instructors in the local high school or college.

Need for Records

The water works operator, suddenly encountering a taste and odor problem, finds it essential that some action be taken immediately to alleviate the condition. His first measure is to make a change in the water treatment process. This change might include increasing chemical dosage, changing the point of chemical application, starting additional treatment, or even decreasing the rate of treatment until proper remedy can be found. Such changes are not based on the assumption that *any* change would be for the better, but on past experience, which has indicated to the operator that improved results were obtained under similar circumstances.

Whether the operator relies on his records or his memory to tell him the necessary treatment changes is probably determined by the frequency with which his problem is encountered, or the completeness of his laboratory records. There is no substitute for accurate and complete records when decisions must be made in a hurry. Records should include type and intensity of tastes and odors, numbers of predominant organisms, treatments used, and results obtained. It is impossible for any one to remember all the details of problems encountered in water works operation, especially when these problems occur at infrequent intervals.

Anticipating Problems

It is well to have diagnosed and prescribed effective treatment for a taste and odor problem; but it would be still better to have anticipated the problem before it reached the customer's attention. Where water supplies are derived from impoundments or lakes this is not very difficult. Algal counts, determined by microscopic examinations to determine algal populations, and water temperature data will help the operator predict potential problems which can be prevented by early corrective treatment.

Most river water supplies cannot be treated to prevent algal growths and the resulting tastes and odors. Some plants, however, resort to continuous free residual chlorination, applications of carbon, or other treatment in anticipation of taste and odors. A few water supplies using river sources have large holding reservoirs which help greatly in anticipating problems and permit corrective treatment to be started before trouble is experienced. In Cincinnati over 3 days' supply is held in reservoirs where free residual chlorination is used for taste and odor control prior to coagulation, settling, and filtering. This is an example of design and operation precautions to insure a uniform quality in the treated water, regardless of sudden unannounced changes in the river.

Some operators may feel that this discussion has been intended primarily for large plants with trained technical staffs. On the contrary, every operator can learn to identify the different species of nuisance organisms—perhaps ten or less in number—which cause most trouble in his plant. He can learn to anticipate the problems caused by these organisms and can apply remedial treatment, based on records of past experience and on the results of experiments carried out at his plant.

Reservoir Problems

In Los Angeles (*53*), the Department of Water and Power has 28 open reservoirs ranging in capacity from 9.4 to 183,500 acre-ft. They are subject to widely diverse climatic and topographic conditions resulting in a great variety of biological activity, which often produces water of unsatisfactory quality. The principal problems are related to pond weed growths, plankton activity, and taste and odor control. Residual copper sulfate treatment has the effect of limiting pond weed growths to a negligible amount. Plankton populations have declined and entirely new seasonal growth patterns have developed in the new environment. Tastes and odors are reportedly the result of complex microbiological decomposition of organic material by actinomycetes or related microorganisms. The improvement in taste is a result of the reduction of food supply to the taste- and odor-producing organism, and possibly of a direct inhibitory effect on the metabolism of the microorganism responsible.

Some reservoirs have sources which supply water rich in both nitrates and phosphates. Growths develop in these waters which are not amenable to copper sulfate treatment. Chlorination has been resorted to as the only means by which all organisms can be controlled. Heavy dosages of liquid chlorine are applied while the reservoirs are in service with excellent results and no taste problems.

Copper and chlorine (*54*), when used together as an algicide, are more effective than is either alone, and a combination of chlorine, copper, and ammonia (cuprichloramine), first used by Harold in England in 1934 (*55*), has been employed at Indianapolis in open service reservoirs and in the distribution system.

Chlorine Dioxide

Ringer and Campbell of Philadelphia reported recently (*45*) on control of algae in a system reservoir using chlorine dioxide. The presence of phosphates stimulated the growth of algae in the open reservoir to the extent that conditions grew intolerable in June 1951. Copper sulfate was applied with unsatisfactory results. Studies in the laboratory established that chlorophyll was oxidized by the chlorine dioxide, with the result that plant metabolism could not be carried on, thus causing the plants to die. The process also seemed to render tasteless and odorless the "essential oils" produced by the algae. After working with copper sulfate and chlorine dioxide for 4 years at the Philadelphia plant, it was concluded that chlorine dioxide is a more effective algicide than copper sulfate and has the advantage of not introducing a detrimental element, such as copper, into the finished water. Taste and odors from the "essential oils" associated with algal growths are eliminated. The cost of chlorine dioxide for providing very good control was nearly double the cost of copper sulfate treatment

which gave only poor control. Ringer and Campbell expressed the belief that the public has the right to expect water of as high quality as modern technology permits.

Filter Problems

M. P. Crabill (*34*) of the Indianapolis Water Company reported in 1941 that filter runs had dropped from 30 hr to 2 hr overnight. Algae had cemented the top $\frac{1}{8}$ in. of sand so that a $\frac{1}{2}$-in. rod could not be forced to penetrate it. *Melosira* was the predominant organism in the water, with a maximum count of about 7,000 organisms per milliliter being carried to the filter. Surface wash was applied for a 2-min period while the filter was standing full; at the end of this time, scum and floating material was drained down to the level of the wash troughs. This operation required 5 min and was performed twice between backwashes. The filter effluent contained 0.2 ppm turbidity when returned to service immediately after refilling. Raw water during this period contained only 5 ppm turbidity, and settled-water turbidity ranged between 1.0 and 1.5 ppm. If higher turbidities had been present, it is probable that more of the algal forms would have been removed in the coagulation process.

Crabill further reported (*32*) that slime and biologic deposits have been eliminated from the filter sand and gravel after free chlorine residuals had been maintained in the filter effluents. Previously, it had been customary to remove the sand and gravel from the rapid filters at about 2-year intervals. The gravel was always found to be slimy, and the bottom layers of sand were sticky. Although the surface wash probably contributed to the improved condition, it is not likely that the surface wash alone was responsible for eliminating biological growths.

Microstraining

Microstraining, a relatively new water treatment process, is used primarily as a pretreatment for the removal of suspended solids and, particularly, nuisance organisms. The microstrainer, a rotating drum covered with a stainless-steel wire fabric, has been developed and used predominantly in the British Isles since 1947. The fabric has approximately 75,000 openings per square inch and the controlling openings have a nominal size of 23–35 μs, a size comparable to the openings in a clean uniform filter sand. Raw water enters the inside of the drum and passes outward through the fabric at straining rates of 4–15 gpm per square foot, depending on the quality of the water. Cleaning is accomplished by means of jets, with the volume of wash water varying from 2 to 10 per cent, depending on the loading (*48*).

A pilot microstrainer was operated on raw Lake Michigan water at the Chicago South District Filtration Plant for approximately 1 year, with an average removal of approximately 82 per cent of the plankton and about 86 per cent of the *Tabellaria, Fragilaria,* and *Asterionella* (diatoms). Indications are that the application of the microstrainer is limited and will not take the place of rapid sand filters; nor, since coagulation is required for turbidity removal, will it replace settling basins (*46*). Recently a contract was let for a microstrainer installation in Norwich, England, to remove *Nais* worms and nematodes from water previously treated by slow sand filtration (*49*). Until the present time, the treatment of water prior to slow sand

filtration has been one of the main applications of this equipment.

Actinomycetes

J. K. G. Silvey has reported (*50*) that in reservoirs of the Southwest tastes and odors could be attributed to actinomycetes and that algae such as *Anabaena, Oscillatoria,* and *Aphanizomenon* furnish adequate nitrogen to support copious actinomycete growths and, consequently, are associated with tastes and odors. According to Silvey, carbon has been an effective treatment in some areas and chlorine dioxide has been relatively effective, while free chlorine usually aggravates the problem.

References

1. Thoman, J. R. Statistical Summary of Water Supply and Treatment Practices in the United States. Pub. 301, USPHS, Washington, D.C. (1953).
2. Poole, B. A. Annual Report of the Public Water Supplies in Indiana. *Year Book–1937.* Indiana State Board of Health, Indianapolis, Ind. (1937).
3. Tarzwell, C. M. & Palmer, C. Mervin. Ecology of Significant Organisms in Surface Water Supplies. *Jour. AWWA,* **43**:568 (Jul. 1951).
4. Filicky, J. G. Taste and Odor Control in Indiana. *Jour. AWWA,* **47**:675 (Jul. 1955).
5. Baylis, John R. Effect of Microorganisms on Lengths of Filter Runs. *W.W. Eng.,* **108**:127 (1955).
6. Amsbary, F. C., Jr. Copper Sulfate for Control of Bacteriological Aftergrowths. *W. W. Eng.,* **99**:182 (1946).
7. Palmer, C. Mervin. Algae of Indiana—A Classified Check List of Those Published Between 1875 and 1928. *Proc. Indiana Acad. Sci.,* **38**:109 (1929).
8. Palmer, C. Mervin & Ingram, William Marcus. Suggested Classification of Algae and Protozoa in Sanitary Science. *Sew. Ind. Wastes,* **27**:1183 (1955).
9. Eddy, S. The Plankton of Lake Michigan. *Illinois Nat. Hist. Survey Bul.,* **17**:203 (1927).
10. Ahlstrom, E. H. The Deep-Water Plankton of Lake Michigan, Exclusive of the Crustacea. *Trans. Am. Microscop. Soc.,* **55**:286 (1936).
11. Daily, W. A. A Quantitative Study of the Phytoplankton of Lake Michigan Collected in the Vicinity of Evanston, Illinois. *Butler Univ. Botan. Studies,* **4**:65 (1938).
12. Damann, K. E. Quantitative Study of the Phytoplankton of Lake Michigan at Evanston, Illinois. *Butler Univ. Botan. Studies,* **5**:27 (1940).
13. Damann, K. E. Phytoplankton Study of Lake Michigan at Evanston, Illinois. *Trans. Illinois State Acad. Sci.,* **33**:68 (1940).
14. Damann, K. E. Plankton Studies of Lake Michigan: 1. Seventeen Years of Plankton Data Collected at Chicago, Illinois. *Am. Midland Naturalist,* **34**:769 (1945).
15. Brinley, F. J. The Effect of Pollution Upon the Plankton Population of the White River, Indiana. *Investigations of Indiana Lakes & Streams,* Indiana Dept. of Conservation, **2**:137 (1942).
16. Coffing, Charlene. A Quantitative Study of the Phytoplankton of the White River Canal, Indianapolis, Indiana. *Butler Univ. Botan. Studies,* **4**:13 (1937).
17. Brinley, F. J. & Katzin, L. J. Distribution of Stream Plankton in the Ohio River System. *Am. Midland Naturalist,* **27**:177 (1942).
18. Palmer, C. Mervin. Plankton Algae of White River in Marion County and Morgan County, Indiana. *Butler Univ. Botan. Studies,* **2**:125 (1932).
19. Ohio River Pollution Control: Supplement F to Part 2, Biological Studies. US Government Printing Office, Washington, D.C. (1944).
20. Hupp, Eugene R. Plankton and Its Relationship to Chemical Factors and Environment in White River Canal, Indianapolis, Indiana. *Butler Univ. Botan. Studies,* **6**:30 (1943).
21. Report of Cooperative Sanitary Survey of White River, Muncie to Anderson, 1925–1930. Dept. of San. Eng., Indiana State Board of Health, Indianapolis, Ind. (1930).
22. Silvey, J. K. G. Tastes and Odors in Water Caused by Microscopic Growths. *W.W. Eng.,* **106**:536 (1953).

23. Quinn, J. L., Jr. Indiana Public Water Supplies. *Monthly Bul., Indiana State Board of Health,* **47**:138 (1944).
24. Juday, C. The Plankton of Turkey Lake. *Proc. Indiana Acad. Sci.,* **4**:1 (1896).
25. Evermann, B. W. & Clark, H. W. *Lake Maxinkuckee, A Physical and Biological Survey: Vol. 2, Biology.* Indiana Dept. of Conservation, Indianapolis, Ind. (1920).
26. Kraatz, W. C. A Quantitative Net-Plankton Survey of East and West Reservoirs, Near Akron, Ohio. *Ohio J. Sci.,* **31**:475 (1931).
27. Palmer, C. Mervin. Algae of Steuben County, Indiana. *Butler Univ. Botan. Studies,* **3**:102 (1934).
28. Daily, W. A. & Miner, E. E. The Phytoplankton of Lake Wawasee, Kosciusko County, Indiana. *Butler Univ. Botan. Studies,* **11**:91 (1953).
29. Draves, H. & Ungurait, D. Taste and Odor Control at Michigan City, Indiana. *Taste & Odor Control J.,* **21**:7:1 (1955).
30. Kinser, R. Preliminary Taste and Odor Survey at Gary, Indiana. *Taste & Odor Control J.,* **21**:1:1 (1955).
31. Baylis, John R. Fishy Odor in Water Caused by *Dinobryon. Pure Water* (Water Purif. Div., Bureau of Eng., Dept. of Public Works, Chicago, Ill.), **3**:138 (1951).
32. Coote, Richard H. & Crabill, Marshall P. Free Residual Chlorination in Indiana. *Jour. AWWA,* **41**:337 (Apr. 1949).
33. Calvert, C. K. The Use of Copper, Chlorine, and Ammonia in Plankton Control. *Jour. AWWA,* **33**:2108 (Dec. 1941).
34. Crabill, Marshall P. Methods of Handling Sand and Gravel. *Jour. AWWA,* **33**:1221 (Jul. 1941).
35. Anon. Evansville, Indiana—Water Works Department. *Chlorination Topics* (Wallace and Tiernan Inc., Belleville, N.J.), **9**:2:1 (1955).
36. Durbin, W. H. Microorganisms in Water at Evansville. *Eng. Record,* **67**:676 (1913).
37. Adams, C. D. Control of Taste and Odor From Industrial Waste. *Jour. AWWA,* **38**:702 (Jun. 1946).
38. Bahlman, Clarence. Water Supply at Cincinnati—New Filtration Plant. *Jour. AWWA,* **33**:1206 (Jul. 1941).
39. Louis, L. Gary Goes to Filters. *Am. City,* **70**:5:99 (1955).
40. Crabill, Marshall P. Fall Creek Treatment Plant at Indianapolis. *W. W. Eng.,* **99**:1051 (1946).
41. Anon. The Case of the Clogged Water Mains. *Am. City,* **62**:2:82 (1947).
42. Calvert, C. K. Discussion—The Bacterial Corrosion of Iron and Steel. *Jour. AWWA,* **33**:165 (Jan. 1941).
43. Morris, M. G. A Study of Bacteria Found in the Distribution System of a Water Plant. *Butler Univ. Botan. Studies,* **8**:82 (1946).
44. Bartuska, James F. Ozonation at Whiting, Indiana. *Jour. AWWA,* **33**:2035 (Nov. 1941).
45. Ringer, Walter C. & Campbell, Sylvester J. Use of Chlorine Dioxide for Algae Control at Philadelphia. *Jour. AWWA,* **47**:740 (Aug. 1955).
46. Baylis, John R. The Microstrainer in Water Filtration. *Public Works,* **82**:5:69 (1951).
47. Silvey, J. K. G., et al. Actinomycetes and Common Tastes and Odors. *Jour. AWWA,* **42**:1018 (Nov. 1950).
48. Hazen, Richard. Application of the Microstrainer to Water Treatment in Great Britain. *Jour. AWWA,* **45**:723 (Jul. 1953).
49. Kelly, S. N. Infestation of the Norwich, England, Water System. *Jour. AWWA,* **47**:330 (Apr. 1955).
50. Silvey, J. K. G. & Roach, A. W. Actinomycetes in the Oklahoma City Water Supply. *Jour. AWWA,* **45**:409 (Apr. 1953).
51. Giannini, A. G. Better Taste and Odor Control Results in Chemical Savings. *Taste & Odor Control J.,* **21**:5:1 (1955).
52. Besozzi, Leo & Vaughn, J. C. Experimental Studies of Odor Control at Whiting, Indiana. *Jour. AWWA,* **41**:1035 (Nov. 1949).
53. Nesin, Benjamin C. & Derby, Ray L. Methods of Controlling Aquatic Growths in Reservoirs (Joint Discussion). *Jour. AWWA,* **46**:1141 (Nov. 1954).
54. Matheson, D. H. Algae Control in Small Water Plants. *Jour. AWWA,* **45**:1238 (Nov. 1953).
55. *Water Quality and Treatment.* Am. Wtr. Wks. Assn., New York (2nd ed., 1950). p. 122.

Palatable Water Is Your City's Best Salesman

The quickest way to be beseiged with complaints is to allow odorous water to get through to your consumers. Such occurrences can be prevented by adequate dosages of AQUA NUCHAR, activated carbon. Odor concentrations can be controlled within palatable limits by running periodic Threshold Odor tests throughout the day, and varying the carbon dosage accordingly.

Our Technical staff will gladly, without obligation, give your plant a complete odor survey and recommend how and where AQUA NUCHAR can best be used to produce palatable water.

GOOD CARBON · GOOD WATER · GOOD WILL

industrial CHEMICAL SALES
division west virginia pulp and paper company

Modern register installed 1955
Original meter purchased 1913
Oil-enclosed type gear train installed 1925
New, current-model measuring chamber assembly installed 1955
Disk piston rebuilt 1925, 1942

How NEW is this Meter?

It was built in 1913 . . . but it's almost as new as 1956. Over the years, working parts have been replaced. Its performance matches every standard of modern metering practice.

The parts used to repair this meter at its last overhaul are identical to those used in the latest Trident meters. They embody every thoroughly tested advancement known to the science of metering.

Designing modern parts to fit "old" meters has been a rigid Neptune policy for over 50 years. It is just one of the extra advantages that make Tridents a better buy . . . both for today and for the years to come.

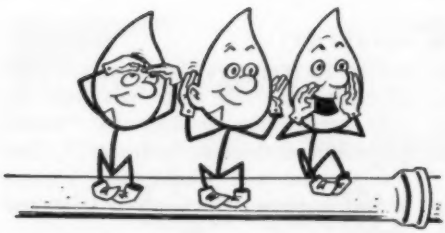
NEPTUNE METER COMPANY
19 West 50th Street, New York 20, N. Y.

NEPTUNE METERS, LTD.
1430 Lakeshore Road, Toronto 14, Ontario

Branch Offices in Principal American and Canadian Cities.

274

neptune



Percolation and Runoff

"All the Water You Need, When and Where You Need It!" may sound a little too much like a campaign promise in these "promising" days. Actually, of course, it does make a mighty good one, and we have an idea that, in one form or other, it will see plenty of service in the campaign now upon us. As it stands here, though, the slogan is intended to point to work to be done rather than pie in the sky—to remind the water works field of the goal toward which it must work if it is to do its job.

Introduced as the keynote of AWWA's expanded public relations program, this concept of the mission of the water works field is certainly not new, but it does seem to have been forgotten. Far too often, water works men under stress seem to have turned to selling excuses and expedients rather than water. How much more effective than the "no-can-doism" of an apology for lack of pressure, a restrictive ordinance, or a call for conservation is the "can-do-butishness" of a positive proposal for providing a supply adequate to every need—how much more effective not only in answering the complaint, but in obtaining action, for the simple fact is that any community can be guaranteed an adequate supply if it is willing to pay for it. Importing polar ice into Texas or piping the Amazon to Southern California—or even building a reservoir in New Jersey—may be extravagantly expensive or discouragingly difficult, but who in these days of mushrooming atoms and interplanetary ideas will call it impossible? At any rate, if a water works man is willing and anxious to provide more water, what nickel-a-ton customer will be able to complain?

The basic idea, of course, is to accentuate the positive. Only by selling water—by emphasizing its worth in present uses, by pointing out new ways in which it can be used, and by encouraging its extended use—can water works really promote public appreciation . . . and demand . . . and support. And support is easy enough to recognize as the key to "All the Water You Need, When and Where You Need It!"

Watershed protection and upstream flood prevention will be aided by a new federal law broadening the Dept. of Agriculture program in this field. The law, which permits facilities for flood control, irrigation, and drainage to be used for municipal water storage as well, was signed by the President even though he objected to a provision that requires the federal government to assume the full cost of building structural works involving flood reduction.

(Continued on page 36 P&R)

(Continued from page 35 P&R)

Kenneth E. Shull, chief chemist and superintendent of purification, Philadelphia Suburban Water Co., has been appointed director of public relations for the company.

The "Just Add Water" promotion has finally reached its logical conclusion in—of all places—the service area of AWWA's President. Perhaps it's because Paul's water makes such a good additive that Atlanta was the place selected for the introduction of "dehydrated water pills." At any rate, one of his customers, an apparently unapocryphal Mrs. Evelyn Henler, admitted to reporters that she had paid 25 cents to a "nice man" who said the pills were a new product that "would revolutionize the water industry." One pill, she was told, would make a quart of water—wonderful for long trips and picnics.

Not the fact that no one else admitted to having been taken in, but the price of the product suggests that the "nice man" may have been one of those "rambling wrecks from Georgia Tech" rather than a professional sharper. A "helluva" salesman, though, rather than an engineer, unless, of course, ...

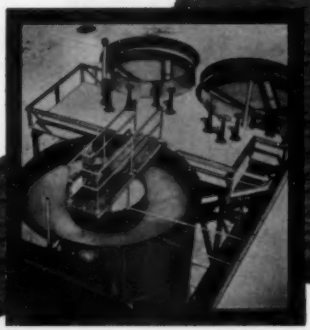
Richard V. Ford, vice-president and export manager of Ford Meter Box Co., Wabash, Ind., takes the oath as director of the Water & Sewerage Industry & Utilities Div. of the Business & Defense Services Administration, US Dept. of Commerce. Swearing him in is BDSA Administrator Charles F. Honeywell.

(Continued on page 38 P&R)

You can have...

15 to 350 gpm high quality water at low cost!

...with the "ACCELAPAK" (trademark) Treating Plant



Designed specifically for small communities, subdivisions, industrial plants, resorts and estates, an "ACCELAPAK" treating plant can be installed at comparatively low cost and requires very little attention in operation. Another example of INFILCO leadership in water-treating equipment, the "ACCELAPAK" plant includes an ACCELATOR® clarifier or softener, slurry feeder, coagulant feeder, rate of flow controller, gravity or pressure filter and other feeders, pumps and purifiers as needed. It is readily adaptable to existing structures.

INFILCO KNOWS HOW . . . to help solve your problem. Over 2000 "ACCELATOR" treating plants are giving efficient, economical and dependable service. If you are tolerating inferior water or makeshift methods of an obsolete plant, investigate this outstanding unit. Write today for Bulletin 1870–JA–07A.

Inquiries are also invited on all other water and waste treating problems including coagulation, precipitation, sedimentation, filtration, flotation, aeration, ion exchange and biological processes.

INFILCO INC.
Tucson, Arizona
The **one** company offering equipment for **all** types of water and waste treatment

FIELD OFFICES IN PRINCIPAL CITIES IN NORTH AMERICA

9607-A

ARE YOU RESPONSIBLE FOR MEASUREMENT OF FLUID FLOW?

Gentile* FLOW TUBES

are impact-type head meters or differential producers.

They are designed to give you guaranteed high accuracy with lowest head loss.

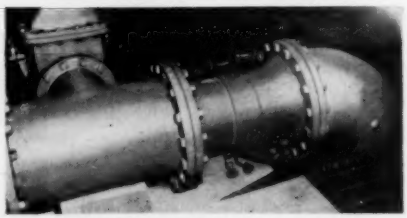
*Gen-Ti-le

You also get:

LOW FIRST COST—Gentile Flow Tubes are economical to purchase.

LOW OPERATING COST—Gentile Flow Tubes require minimum maintenance. Where purging or back-flushing is a normal routine, the Gentile Flow Tube can be arranged for constant or intermittent purging without removing from the line.

LOW INSTALLATION COST—Gentile Flow Tubes can be installed with no straight run upstream or downstream, except where near valves or regulators.



Actual installation of a 16" Flow Tube for REVERSE FLOW. Note fittings (elbow and tee) are bolted directly to flanges of Flow Tube.

Gentile Flow Tubes can be furnished with or without suitable secondary indicating, recording, or totalizing instruments.

GENTILE Flow Tubes are manufactured exclusively by Foster Engineering Company

Write for further information or specific recommendations.

FOSTER ENGINEERING COMPANY

835 LEHIGH AVENUE UNION, N. J.

AUTOMATIC VALVES • CONTROL VALVES
SAFETY VALVES • FLOW TUBES

(*Continued from page 36 P&R*)

JCUMWE, pronounced, we are told, ja-kum'-wee, and meaning, we imagine, "yes, we come," is actually already here. And a good thing, too, we think, for its purpose, "to secure uniformity of methods of water examination," is an end desired by all and certainly by those whose water examinations involve legal responsibility. JCUMWE, if you haven't psyched it, means Joint Committee on Uniformity of Methods for Water Examination, and the joint now includes an even dozen organizations that "prepare, adopt, and publish, for general public distribution, water examination methods which are in general use":

American Petroleum Institute
American Public Health Association
American Society of Mechanical Engineers
American Society for Testing Materials
American Water Works Association
Association of Official Agricultural Chemists
Federation of Sewage & Industrial Wastes Associations
Manufacturing Chemists Association
Technical Association of the Pulp & Paper Industry
United States Geological Survey
United States Pharmacopoeial Convention
United States Public Health Service

With APHA representative F. W. Gilcreas as chairman, Arthur Thurn of TAPPI, vice chairman, and C. K. Rice of ASTM, secretary, the committee is preparing to review the new methods developed by all participating organizations with the purpose of recommending the use of the same methods for the same purposes and of suggesting changes to bring about uniformity of terminology and of such details as sampling methods, apparatus and reagents, procedure, and reporting of results.

The membership of APHA, AWWA, and FSIWA on the Joint Committee will in no way affect the cooperative

(*Continued on page 40 P&R*)

STEEL PIPE guarantees LOWER underground OVERHEAD

When you choose strong, dependable steel pipe you lay the groundwork for a water system that costs you less and saves you more. In the first place, steel pipe usually costs no more to buy. Lightweight steel pipe costs less to ship and handle. It's easier and faster to install, requires less labor and equipment. Longer lengths mean fewer sections to handle, fewer couplings to install. But your biggest savings come over years of trouble-free service with minimum maintenance. Tight, leakproof joints prevent water waste. Resistance to shock and breaks virtually eliminates costly repairs and interruptions to service. And corrosion-proof linings and coatings ensure maximum flow at lower pumping costs.

Any way you look at it . . for underground, surface or suspension installations . . . to keep your pipeline overhead down, you're smart to specify STEEL pipe.

"WHEREVER WATER FLOWS—STEEL PIPES IT BEST"

STEEL PLATE FABRICATORS ASSOCIATION

79 W. MONROE ST., CHICAGO 3, ILL.

(*Continued from page 38 P&R*)

relationship of these three societies in the preparation of *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* Whereas that activity is an actual publication partnership, the function of JCUMWE is strictly advisory. At the moment, the *Standard Methods* Joint Editorial Board for the eleventh edition is both organized and active, with the first business meeting scheduled for next month. Michael Taras of the Detroit Dept. of Water Supply is AWWA representative on this board, with F. W. Gilcreas representing APHA and Gail Edwards, FSIWA. *Standard Methods* methods will, of course, be put through the JCUMWE review routine—probably at the point where the various subcommittees submit the first drafts of their recommended methods—and its recommendations toward uniformity will be considered along with the criticisms of the other review committees involved.

All of this may sound complicated in more than pronunciation. Certainly it should indicate why it will be at least 5 years before a new edition of *Standard Methods* is issued. What it really should add up to, though, is more standard methods—more standard *Standard Methods* methods, that is.

Willard F. Rockwell, board chairman of Rockwell Mfg. Co., has been knighted by the Italian government in the order "Al Merito Della Repubblica." The honor, usually reserved for Italian citizens, was conferred on Col. Rockwell for his "outstanding contributions to Italy's reconstruction and economic recovery."

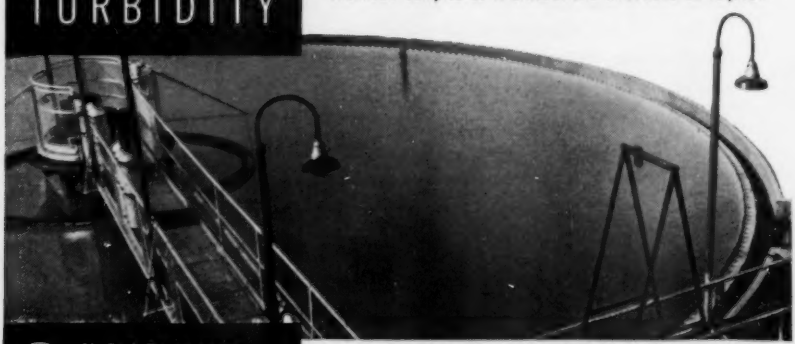
(*Continued on page 44 P&R*)

N-Sol
ACTIVATED SILICA
CLEARS UP
TURBIDITY

When raw water turbidity is high, N-Sol coagulant aid helps you to get

- **sparkling clear water**
- **increased filter capacity**

The N-Sol floc is large and tough—enmeshes more impurities; settles fast. Convince yourself with jar tests. Activated silica sol is made from our N sodium silicate and a reacting chemical. Samples of N silicate and directions on request.



N-Sol Processes
PQ Sodium Silicates

1831 • 125th ANNIVERSARY • 1956 Trademarks Reg. U.S. Pat. Off.
PHILADELPHIA QUARTZ COMPANY
1142 Public Ledger Bldg., Philadelphia 6, Pa.

with **CLOW** *mechanical joint*

SPLIT SLEEVES

Don't be caught short this winter without a stock of Mechanical Joint Split Sleeves. Be prepared with sleeves for every size pipe in your system. Clow split sleeves fit all classes of cast iron pipe, and make a fast, simple, permanent repair.

F-1200 Straight Split Sleeves will repair breaks in the barrel of the pipe. F-1205 Bell Split Sleeves will repair damaged joints of underground pipe, as well as the barrel.

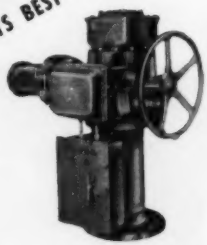
Clow Split Sleeves are shipped complete with joint accessories. All sizes 3″ through 16″ available for immediate shipment.

James B. Clow & Sons
Inc.
201-299 N. Talman Avenue, Chicago 80, Illinois
Subsidiaries: Eddy Valve Company • Iowa Valve Company

CLOW CHICAGO

VALVE ACTUATION

ENGINEERING AT ITS BEST



Motor Operated Stand with Integral Control Equipment

MOTOR OPERATED VALVE

Power actuation is available as a complete carefully engineered unit. Actuation may be by electric motor, air motor, or air or fluid cylinder type motivation. The power unit is compact and self contained, with sturdy supports which attach to the top of any Ludlow Valve.

Manual operation is provided for all electric and air motor operated valves. Our engineers will be glad to help you lay out a plan based on the many years of Ludlow experience in power actuation systems of all kinds for all purposes.

"NO POSSIBLE DIFFERENCE IN FIRST COST CAN OVERBALANCE THE PERPETUAL ECONOMY OF QUALITY."

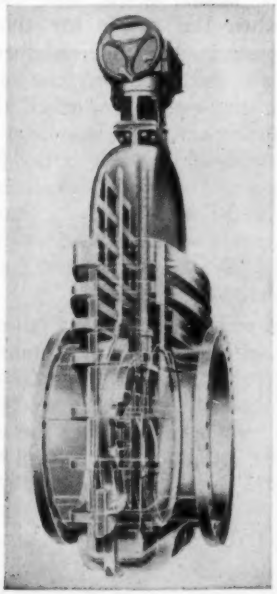
19

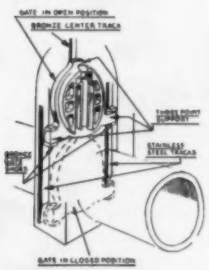
CYLINDER OPERATED VALVE

THE LUDLOW VALVE MFG. CO., INC. TROY, N.Y.

TRADE LUDLOW MARK

GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES
CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES





SQUARE BOTTOM VALVES

The Rensselaer Square Bottom Valve may well be called the "work horse" of the valve family. It is built to stand up under the severe conditions found in automatic operation, throttling, differential pressures and the constant opening and closing found in filtration plants and process industries.

A three-point gate support holds the downstream gate away from its seat ring at all points of travel except the final, fully closed position. Any tendency for the downstream gate to tilt and score the face of the seat ring under conditions of high water velocity or throttling service is eliminated.

At all points this valve is built for long life under constant and severe operation.

IN OPENING: the shoes slide up the stainless steel track inclines to the higher level of the tracks, lifting the gate clear of the bronze seat ring.

IN CLOSING: the gate does not come in contact with the bronze seat ring until the closing point is reached. Even when partly open, the gate is held away from the seat, eliminating all wear due to vibration.

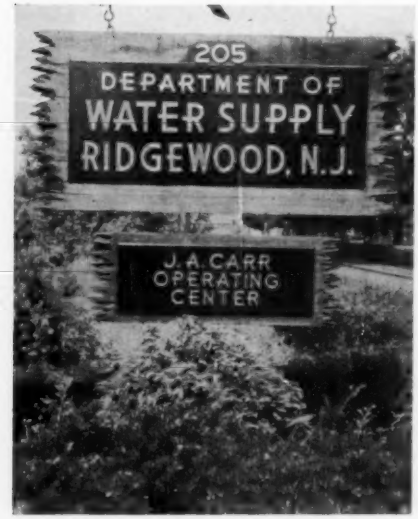
Rensselaer Square Bottom Valves are made in sizes from 4 to 48" with any type end connection. By-passes, spur or bevel gearing, and cylinder or motor operation as desired. 20

Rensselaer
VALVE CO. TROY, NEW YORK

DIVISION OF
THE LUDLOW VALVE
MANUFACTURING CO., INC.

GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES
CHECK VALVES • TAPPING SLEEVES • AIR RELEASE VALVES

(Continued from page 40 P&R)

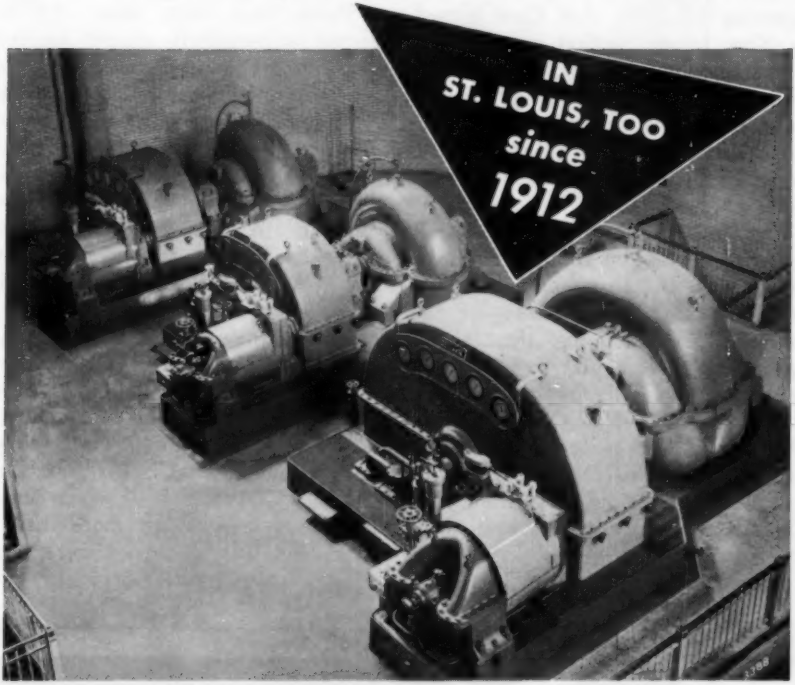


Namings make news, too—particularly when the names are those of distinguished AWWA members. Thus, we are glad to reproduce here evidence of the esteem in which the late J. Arthur Carr, superintendent of the Ridgewood, N.J., water utility for almost 40 years, and H. S. Morse, now chairman of the board and for more than 30 years executive head of the Indianapolis Water Co., have been held by their communities.

The sign pictured at the left reflects the action of the Board of Commissioners of the Village of Ridgewood, who posthumously gave this recognition to the man who had been the village's water supply chief from 1914 through 1953. A member of AWWA

(Continued on page 46 P&R)

DE LAVAL pumps America's water . . .



The three De Laval turbine-driven centrifugal pumps (shown above) have given dependable service in the Howard Bend Station of the St. Louis, Mo. water works system for more than a quarter of a century. The two smaller units have a capacity of 60 mgd and the larger one of 120 mgd, all designed to deliver against 40 ft. head.

In the St. Louis Chain of Rocks Station, De Laval pumps have an even longer service record. Two 40 mgd units were installed in 1912 and a 100 mgd unit in 1918. Two of these three pumps are still on the line. The third has been altered and is still in constant service.

For St. Louis' expanding needs, De Laval is now building ten more centrifugal pumps with a total capacity of 450 million gallons per day.

Write for your copy of new De Laval Bulletin 1004

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY

822 Nottingham Way, Trenton 2, New Jersey

DL356A

(Continued from page 44 P&R)

beginning in 1916, Art Carr served the New Jersey Section in a variety of posts and offices, including chairman and national director. A Fuller Awardee, Art is also remembered for co-fathering, with Jim Harding, the Association's specifications for deep wells.

The unveiling shown on p. 44 took place Jul. 31 at the new Morse Reservoir near Indianapolis, with Scott and Kent Morse, grandsons of the reservoir Morse, doing the honors that helped to recognize "a significant contribution to the growth of Indianapolis." A member of AWWA since 1925, "H.S." was twice national director for the Indiana Section, its Fuller Awardee in 1953, and became an Honorary Member of the Association in 1952.

There have been other AWWA names in relatively recent namings, too. At Memphis not long ago, contracts were let for the C. M. McCord Pumping Station, named for the water division's recently retired director (see story P&R p. 48) and the Kentucky-Tennessee Section's former national director. At Denver, last year, the water commissioners honored former AWWA director D. D. Gross for his 52 years in the service of the city by naming its newest dam after him, and by having Miss America do the christening. At Columbus, Ohio, meanwhile, a midwestern Hoover Dam has been named in honor of two Hoovers —Superintendent C. B. and Chief Chemist C. P.—each of whom served the water division for more than 40 years and both of whom were active

(Continued on page 48 P&R)

Type SM with Worm Gear Drive on Butterfly Valve.

See the newest developments in Mechanical Power Transmission at our Booth #80 — 22nd National Power Show, New Coliseum, New York City, November 26-30.

Limitorque® VALVE CONTROLS

From coast to coast, hundreds of LimiTorque Controls are in service in central stations and power plants for automatic or push-button operation of valves up to 120 inch diameter. Why is acceptance so widespread? Because LimiTorque Operators are designed to provide dependable, safe and sure valve actuation at all times.

LimiTorque is self-contained and is applicable to all makes of valves. Any available power source may be used to actuate the operator: Electricity, water, air, oil, gas, and are readily adapted to Microwave Control.

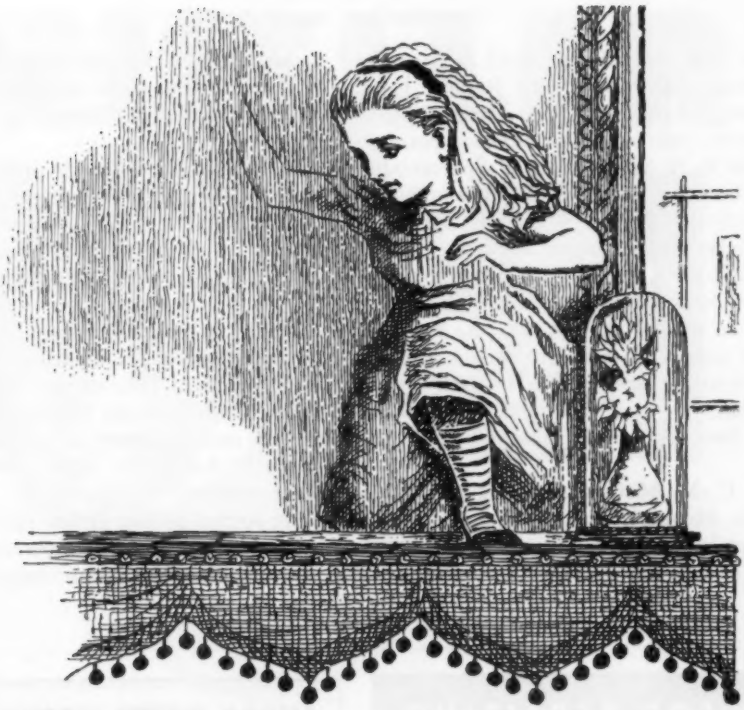
A feature of LimiTorque is the torque limit switch which controls the closing thrust on the valve stem and prevents damage to valve operating parts.

Write for Catalog L-550

Philadelphia Gear Works, Inc.

ERIE AVE. and G STREET, PHILADELPHIA 34, PA.

NEW YORK • PITTSBURGH • CHICAGO • HOUSTON • LYNCHBURG, VA. • BALTIMORE • CLEVELAND



The time has come . . . to speak of many things ABOUT CHLORINATORS

You needn't be confused, Alice . . . you are in a modern chlorinator wonderland. Although two chlorinators may look the same, one is but a looking-glass reflection of the real one. The F&P Chlorinator, Alice, is the *real* one, so superior in engineering design and construction, accepted and proven in thousands of installations that others must *try* to imitate it.

There are many things, Alice, that are found only in the F&P Chlorinator. For instance, the F&P Chlorinator is the *only* chlorinator with a single stack controller, the result of a constant program of improvement. Materials that appeared sound 4 years ago have been discarded by F&P and replaced with better materials. Imitations do not benefit from this experience. Only F&P has the experience to supply you with a proven, instrument type, completely corrosion-resistant chlorinator. Don't buy an *untried* Chlorinator.

Other things, too, Alice . . . things called intangibles, can't be copied. Such things as dependability, simplicity and experience. So you see—things can "look alike" and not be at all.

If *you're* confused about chlorinators there's one sure way to sweep away *all* confusion. Ask for a free trial of the F&P Chlorinator. Put it to any test you can devise, try it until you're convinced the F&P Chlorinator is far and away better than any other chlorinator ever devised, works better, costs less at the outset and less to maintain. You can't beat it. Write today for complete information and absolute money back guarantee.

FP FISCHER & PORTER

1006 Fischer Road, Hatboro, Pa. LA1119B

(Continued from page 46 P&R)

in AWWA affairs. And at Spartanburg, S.C., and Cedar Rapids, Iowa, two former AWWA directors have given their names to filtration plants—the R. B. Simms plant at Spartanburg, where the namee is still superintendent, and the H. F. Blomquist plant at Cedar Rapids, upon his retirement in 1951 after 29 years as superintendent.

There must be much more nameness than that reported here. As a matter of fact, if the practice persists, as we're certain it should, the nation's list of water facilities will one day sound like a back issue of the AWWA Directory.

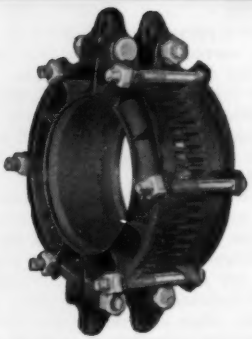
C. M. McCord, retiring director of the Memphis, Tenn., Water Div., will not be forgotten by the city he served; a new pumping station has been named in his honor. His successor is Justin J. Davis, former chief engineer of water distribution at Memphis.

R. S. Ingols, research professor at Georgia Inst. of Technology, Atlanta, has departed for Italy, where he will lecture on chemistry in Milan, under the Fulbright Fellowship program.

Ross L. Clark, formerly deputy commissioner of the Drainage & Sewage Treatment Div. of the Metropolitan Toronto Dept. of Works, has been named commissioner of works. He succeeds Leslie B. Allan, who has been relieved of the duties of this office so that he can devote full time to his position as commissioner of roads, which he has held simultaneously.

(Continued on page 50 P&R)

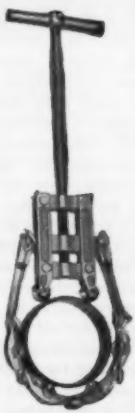
FOR REPAIRING BROKEN MAINS



Skinner Seal Split Coupling Clamp. One man can install in 5 to 15 minutes. Gasket sealed by Monel band. Tested to 800 lbs. line pressure. A lasting repair. 2"-24" inclusive. Write today for new catalog.

M. B. SKINNER CO.
SOUTH BEND 21, INDIANA, U.S.A.

AMONG WATER WORKS MEN



THE HEAVY-DUTY
ELLIS
PIPE CUTTER
IS *BEST*

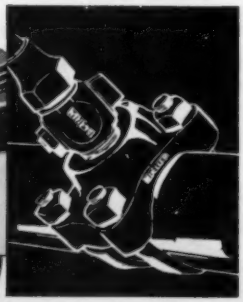
FOR CUTTING LARGE SIZES OF PIPE

No. 01 Cuts Pipe 4" to 8"
No. 1 Cuts Pipe 4" to 12"

Write for circular and price list No. 39J, on our complete line of pipe cutting tools.

ELLIS & FORD MFG. CO.
2425 Goodrich Ave. Ferndale, Michigan
Phone Lincoln 7-3600

MUELLER®



Service Clamp
Tapping size ½" through 2"
Iron pipe or Mueller thread
Neoprene or lead ring gasket
Single or double strap
Pipe sizes 1" through 12"

Connect services to any main!

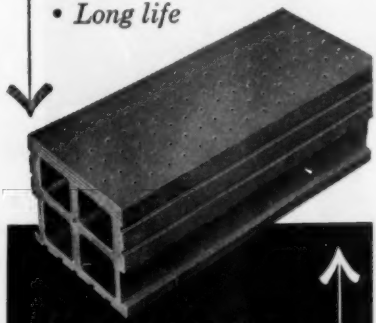
Make service connections quickly and easily to steel, cast iron and all classes of asbestos cement mains. Depending upon the size required, the Mueller "E-4" or "D-4" drilling machine may be used to activate the service, under pressure, without loss of water.

Mueller service clamps with single or double strap fit main sizes through 12". Clamps are machine-threaded with I.P. or Mueller thread to receive Mueller corporation stops with a wide variety of outlets.

Contact your Mueller Representative or write direct for complete information.

MUELLER CO.
Dependable Since 1857
MAIN OFFICE & FACTORY DECATUR, ILLINOIS

- *Permanence*
- *No tuberculation*
- *Equal distribution*
- *Uniform filtration*
- *Low loss of head*
- *Acid, alkali-resistant*
- *Long life*



You get ALL these advantages with

LEOPOLD

Glazed Fire Clay TILE FILTER BOTTOMS

Made of highest quality de-aired fire clay—vitrified and salt glazed, the Leopold Filter Bottom requires only a shallow depth of small sized, inexpensive filter gravel to support the filtering medium. Further, the laterals and distributing blocks are all combined in one strong permanent unit that will last indefinitely.

Adaptable to any rectangular filter unit, the Leopold Glazed Tile Filter Bottom is designed to successfully meet all underdrain requirements.

Write for details!

F. B. LEOPOLD CO., INC.
2413 W. Carson Street
Pittsburgh 4, Pa.

(*Continued from page 48 P&R*)

Armco Drainage & Metal Products, Inc., has consolidated its Iowa-Nebraska and Missouri-Kansas divisions into a new Midwestern Div., to be managed by A. J. Mistler, with headquarters at Topeka, Kan. Mistler was formerly manager of the Missouri-Kansas Div.

The high bill blues have been sung so many times to so many water works men that their handling has become a routine, and many utilities have set up leakage allowances or systems of splitting excess quantities to ease the burden on their customers. Robert R. Ferry of Scarborough, N.Y., wasn't that lucky when he received a quarterly bill of $900 recently, for when water department workers investigated they found two breaks in the 600-ft service from the street line to the Ferry home. As a matter of fact, the discovery cost him an additional $1,600 instead, for that was the price of a new service line. More fortunate was the Wright Aeronautical Div. of Curtiss Wright Corp., which complained last May that its water bills were skyrocketing unaccountably. Investigation there revealed that some foreign matter had lodged in the measuring chamber of the meter, causing it to overregister some 140 mil gal from November 1955 to May 1956, representing a credit of $8,000 to the customer. As for Charles Hlavac, resident of Cleveland's suburban Seven Hills, his bill for $171, complete with figures on quantity consumed between December 1951 and May 1956, seems to have been a matter of mind over meter. At any rate, the Hlavac home had never been hooked up to the city system. Which is only to suggest that occasionally it's high bill blooey!

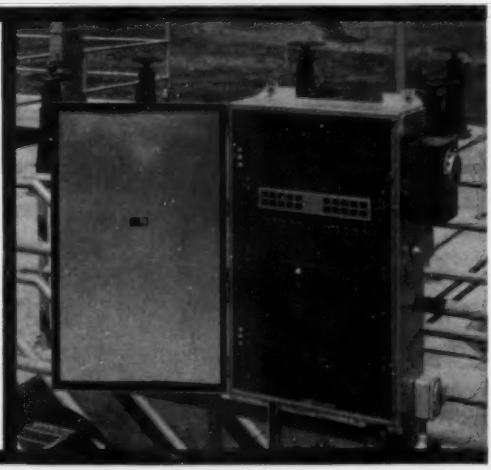
(*Continued on page 52 P&R*)

Sparton

well field control systems

SAVE SUPERVISORY HOURS • MINIMIZE POWER FAILURE DOWNTIME • ASSURE EMERGENCY WATER • ENABLE ACCURATE PROGRAMMING . . . with FULL FLEXIBILITY for expansion.

Sparton multi-channel scanning system ties one to 25 wells to treatment plant, eliminates restart delays, minimizes downtime due to storm induced failures, assures emergency water.



Your solution to well shut-down, restart delays, and lost supervisory time — dependable Sparton well field controls — proven on the storm-driven plains, in river floodlands, under heavy municipal load. For reliable centralized supervision, these systems employ trouble-free d.c. telegraphy and/or tone techniques over conventional transmission or telephone line. They're tailored to your exact needs, yet offer installation economies through use of standard, pre-engineered control modules.

Sparton

CONTROL SYSTEMS

SPARTON CONTROL SYSTEMS DIVISION
The Sparks-Withington Company
Jackson, Michigan

☐ Please send control brochure
☐ Have representative call

Name_____ Title_____
Company_____
Address_____
City_____ Zone____ State_____

DESIGNERS

4 MAJOR JOB ADVANTAGES

now offered by
DU PONT

•

Interesting, challenging, professional work assignments.

•

Long-range company programs assuring stability.

•

Promotion-from-within policy assuring opportunities for advancement.

•

Varied technical and administrative training programs.

•

IMMEDIATE OPENINGS FOR:
Sanitation Designers

Apply today for a position that will allow you to realize your full potential as a designer. Your work will be in a wide range of increasingly important fields.

Please send complete resume, including details of education and experience, to:

Mr. T. J. Donovan
Engineering Department

DU PONT

Better Things for Better Living
...through Chemistry

E. I. du Pont de Nemours & Co., Inc.
Wilmington 98, Delaware

(Continued from page 50 P&R)

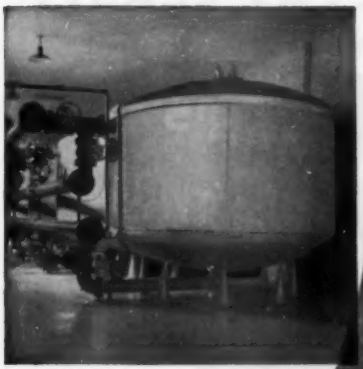
L. E. Burney has been appointed to succeed Leonard A. Scheele as US surgeon general, subject to Senate confirmation. As surgeon general, Dr. Burney will head the US Public Health Service, of which he has been a member since 1932, with a leave of absence in 1945–54 to serve as secretary of the Indiana Board of Health. In 1954 he returned to federal service as assistant surgeon general. Dr. Scheele resigned in July to join a pharmaceutical firm.

Down under, things seem a little upside down, but, thereby, perhaps, a lot more sensible. From Sydney, Australia, comes news that an unidentified man has been sponsoring a "drink more water" campaign. As part of the advertising, his suggestion, "For the nation's sake and your good health, drink eight glasses of water a day," has been flashed on the screen every show at 32 of Sydney's movie theaters. Of course, our anonymous plugger could well be AWWA member Thomas B. Nicol, engineer in charge of the metropolitan water board there, trying to drum up some trade—an estimated 1 mgd, in fact, if everyone were to follow the advice. If it were a water board campaign, it would indeed seem upside down to many of our "up over" water workers, whose advertising efforts these days seem more and more bent on coaxing conservation—on urging less business, that is. Of course, gravity being what it is, supplies *should* be more abundant both down and under.

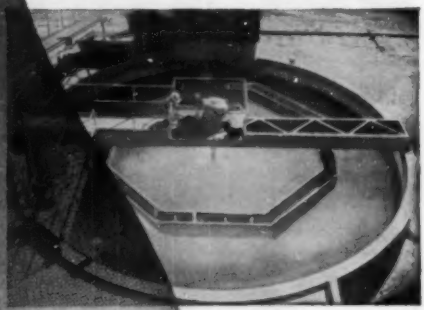
J. L. McClure has retired as superintendent of the Commerce, Ga., Water & Light Dept. His successor is J. E. Wood, formerly superintendent of public works at Union, S.C.

(Continued on page 80 P&R)

Why General Filter?



There are many reasons why municipalities and industries have installed General Filter water treating plants:



INSTALLATION SUPERVISION . . . General Filter "job-engineers" each installation to the consulting engineer's specification . . . supervises the installation and trains the personnel who will work with the equipment.

OPERATIONAL DEPENDABILITY . . . for twenty years General Filter has concentrated all of its efforts toward "better water treatment". Their efforts have produced water treating plants and equipment that are *completely* dependable.

ENGINEERING KNOW-HOW . . . General Filter's design and construction engineers are familiar with the problems involved in water treatment.

GREATER ECONOMY . . . the only real test of economy is a long term test. General Filter plants stand up over the years providing "better water" with minimum maintenance, longer trouble-free, smoother operation.

Find out why you should specify General Filter . . . Write today for detailed information regarding your water treatment problems.

General Filter Company
AMES, IOWA
. . . *better water*

AERATORS • FILTERS • TASTE AND ODOR • ALKALINITY CONTROL • HIGH CAPACITY
RESINOUS ZEOLITE • IRON RUST REMOVAL • DEMINERALIZATION • SOFTENERS

Multiplies Bearing Contact Area by SIX . . . *AT LEAST!*

CHAPMAN'S Beamed Waterway GATE VALVE

With Chapman's Beamed Waterway Valve, in the partly open position, you get *six to ten* times more bearing contact surface. That's six to ten times more bearing contact surface than you could get from any other double disc parallel seat or square bottom gate valve. No wonder it leads the preferred list for Filtration Plants, Wash Water Service, or other similar limited throttling use.

Operation is smooth. They seat snugly. There's little or no leakage. Bronze bearing surfaces on beams and downstream discs are rugged. Their long useful life . . . with top-notch performance and lowest maintenance . . . is measured in decades, not just years. This applies to all sizes . . . with any desired method of operation.

Outside of a stamp, it costs nothing to get all the facts. You'll find them in our Catalog No. 45 . . . an informative digest devoted exclusively to Chapman Beamed Waterway Gate Valves.

Why not write for it . . . now!

THE CHAPMAN VALVE MANUFACTURING COMPANY
INDIAN ORCHARD, MASSACHUSETTS

Professional Services

ALBRIGHT & FRIEL, INC.

Consulting Engineers

Water, Sewage, Industrial Wastes and Incineration Problems
City Planning, Highways, Bridges and Airports
Dams, Flood Control, Industrial Buildings
Investigations, Reports, Appraisals and Rates

Three Penn Center Plaza Philadelphia 2, Pa.

ALVORD, BURDICK & HOWSON

Engineers

Water Works, Water Purification, Flood Relief, Sewage Disposal
Drainage, Appraisals, Power Generation

20 North Wacker Drive Chicago 6

AYRES, LEWIS, NORRIS & MAY

Consulting Engineers

Louis E. Ayres — Robert Norris
George E. Lewis — Donald C. May
Stuart B. Maynard — Homer J. Hayward

Waterworks, Sewerage, Electric Power

500 Wolverine Building, Ann Arbor, Michigan

A. S. BEHRMAN

Chemical Consultant

Water Treatment
Ion Exchange Processes and Materials
Patents

9 S. Clinton St. Chicago 6, Ill.

BLACK & VEATCH

Consulting Engineers

4706 Broadway, Kansas City 2, Mo.

Water Supply Purification and Distribution; Electric Lighting and Power Generation, Transmission and Distribution; Sewerage and Sewage Disposal; Valuations, Special Investigations and Reports

BLACK AND ASSOCIATES, INC.
BLACK LABORATORIES, INC.

Engineers and Chemists

Water, Sewerage, Hydrology, Waste Treatment
Complete Laboratory Services

700 S. E. 3rd St. Gainesville, Fla.

BOGERT and CHILDS

Consulting Engineers

Clinton L. Bogert — Fred S. Childs
Ivan L. Bogert — Donald M. Ditmars
Robert A. Lincoln — Charles A. Manganaro
William Martin

Water & Sewage Works — Refuse Disposal
Drainage — Flood Control
Highways and Bridges — Airfields

145 East 32nd Street, New York 16, N. Y.

Bowe, Albertson & Associates

Engineers

Water and Sewage Works
Industrial Wastes—Refuse Disposal—Municipal Projects
Industrial Buildings—Reports
Plans—Specifications
Supervision of Construction and Operation—Valuations
Laboratory Service

75 West Street New York 6, N.Y.

BROWN AND CALDWELL

Civil and Chemical Engineers

Water—Sewage—Industrial Waste
Consultation—Design—Operation
Chemical and Bacteriological Laboratories

66 Mint Street San Francisco 3

BUCK, SEIFERT AND JOST

Consulting Engineers

Water Supply—Sewage Disposal—Hydraulic Developments

Reports, Investigations, Valuations, Rates, Design, Construction, Operation, Management, Chemical and Biological Laboratories

112 E. 19th St., New York 3, N. Y.

Professional Services

BURGESS & NIPLE

Consulting Engineers

(Established 1908)

Water Supply, treatment and distribution
Sewage and industrial wastes disposal
Investigations, reports, appraisals, rates
Laboratory Municipal engineering
Supervision

2015 W. Fifth Ave. Columbus 12, Ohio

CAUSEY AND WEEKS

ENGINEERS

Designers • *Consultants*

Water Supply and Purification
Sewerage and Sewage Treatment
Investigations and Reports
Supervision of Construction

Streets and Highways

6165 E. Sewells Point Road, Norfolk 13, Va.

BURNS & McDONNELL

Engineers—Architects—Consultants

Kansas City, Mo. Phone
P.O. Box 7088 DElmar 3-4375

THE CHESTER ENGINEERS

Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants—Incineration—Gas Systems
Valuations—Rates—Management
Laboratory—City Planning

601 Suismon Street
Pittsburgh 12, Penna.

JAMES M. CAIRD

Established 1898

C. E. Clifton, H. A. Bennett

Chemist and Bacteriologist

WATER ANALYSIS
TESTS OF FILTER PLANTS

Cannon Bldg. Troy, N. Y.

CHAS. W. COLE & SON

Engineers—Architects

Sewerage, Water Supply, Bridges,
Highways, Toll Roads, Industrial, Municipal
and Commercial Buildings

220 W. LaSalle Ave. South Bend, Indiana
Central 4-0127

CAMP, DRESSER & McKEE

Consulting Engineers

Water Works, Water Treatment,
Sewerage and Wastes Disposal,
Flood Control

Investigations, Reports, Design
Supervision, Research, Development

6 Beacon St. Boston 8, Mass.

CONSOER, TOWNSEND & ASSOCIATES

Water Supply—Sewerage
Flood Control & Drainage—Bridges
Ornamental Street Lighting—Paving
Light & Power Plants—Appraisals

351 E. Ohio St. Chicago 11

CAPITOL ENGINEERING CORP.

Consulting Engineers

Water Works, Sewage Disposal, Airports,
Dams and Bridges, Roads and Streets,
Planning, Design and Surveys.

Dillsburg, Pa.

Rochester, N. Y. Dallas, Texas

Cotton, Pierce, Streander, Inc.

Associated Consulting Engineers

E. R. Cotton P. B. Streander
G. A. Gieseke H. G. Damon
I. J. Silverstone

Water Supply, Water Purification
Sewerage, Sewage Treatment
Refuse Disposal

132 Nassau Street 55 Caroline Road
New York 38, N.Y. Gowanda, N.Y.

DE LEUW, CATHER & COMPANY

Water Supply — Sewerage
Railroads — Highways

Grade Separations—Bridges—Subways
Local Transportation

Investigations—Reports—Appraisals
Plans and Supervision of Construction

150 N. Wacker Drive, Chicago 6 — 79 McAllister St., San Francisco 2

GARRITY & MOSHER

Engineers

Leo V. Garrity — L. W. Mosher

Municipal and Industrial Water and Sewage Works
Water System Analyses
Tunnels and Foundations
Reports, Designs, Plans and Specifications

14050 W. McNichols Rd. — Detroit 35, Mich.

Fay, Spofford & Thorndike, Inc.

Engineers

Water Supply and Distribution — Drainage
Sewerage and Sewage Treatment
Airports — Bridges — Turnpikes

Investigations — Reports — Valuations
Designs — Supervision of Construction

Boston, Massachusetts

Glace & Glace, Inc.

Civil and Sanitary Engineers

Water Supply, Purification and Distribution, Dams, Sewerage, Sewage and Industrial Waste Treatment
Investigations, Reports, Designs
Supervision of Construction and Operation

1001 North Front Street, Harrisburg, Penna.
Wash., D.C.—Easley, S. C.—Tallahassee, Fla.

FINKBEINER, PETTIS & STROUT

Carleton S. Finkbeiner — Charles E. Pettis
Harold K. Strout

Consulting Engineers

Reports, Designs, Supervision,
Water Supply, Water Treatment, Sewerage,
Sewage Treatment, Wastes Treatment,
Valuations & Appraisals

518 Jefferson Avenue — Toledo 4, Ohio

GREELEY AND HANSEN

Engineers

Water Supply, Water Purification
Sewerage, Sewage Treatment
Refuse Disposal

220 S. State Street, Chicago 4

FREESE & NICHOLS

Fort Worth, Texas

FREESE, NICHOLS & TURNER

Houston, Texas

Industrial and Municipal Engineering—Water Supply and Purification—Sewerage and Industrial Waste Treatment—Highways and Structures — Dams — Drainage Works — Airports—Investigations—Valuation—Design and Supervision.

WILLIAM F. GUYTON & ASSOCIATES

Consulting Ground-Water Hydrologists

Underground Water Supplies
Investigations, Reports, Advice

307 W. 12th St., Austin 1, Texas, Phone: GR-7-7165
3301 Montrose Blvd., Houston 6, Texas, Phone: JA-2-9885

FROMHERZ ENGINEERS

Structural—Civil—Sanitary

Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations

Investigations; Reports; Plans and Specifications; Supervision

New Orleans

FRANK E. HARLEY, C. E.

Consulting Engineer

Water Supplies, Highways
Municipal Problems

260 Godwin Ave.
Wyckoff, N.J.

GANNETT FLEMING CORDDRY & CARPENTER, Inc.

Engineers

Water Works—Sewerage
Industrial Wastes—Garbage Disposal
Roads—Airports—Bridges—Flood Control
Town Planning—Appraisals
Investigations & Reports

Harrisburg, Pa. — Philadelphia, Pa.
Pittsburgh, Pa. — Daytona Beach, Fla.

HASKINS, RIDDLE & SHARP

Consulting Engineers

Water—Sewage & Industrial Wastes—Hydraulics
Reports, Design, Supervision of Construction, Appraisals, Valuations, Rate Studies

1009 Baltimore Avenue — Kansas City 5, Mo.

Professional Services

THE JENNINGS-LAWRENCE CO.

Civil & Municipal Engineers
Consultants

Water Supply, Treatment & Distribution
Sewers & Sewage Treatment
Reports—Design—Construction

1392 King Avenue Columbus 12, Ohio

HAVENS & EMERSON

W. L. Havens A. A. Burger
J. W. Avery H. H. Moseley
F. S. Palocsay E. S. Ordway
F. C. Tolles, Consultant

Consulting Engineers

Water, Sewage, Garbage, Industrial Wastes, Valuations—Laboratories

Leader Bldg. CLEVELAND 14
Woolworth Bldg. NEW YORK 7

JONES, HENRY & WILLIAMS

Consulting Sanitary Engineers

Water Works
Sewerage & Treatment
Waste Disposal

Security Bldg. Toledo 4, Ohio

HAZEN AND SAWYER

Engineers

Water and Sewage Works
Industrial Waste Disposal
Drainage and Flood Control
Reports, Design, Supervision of Construction and Operation
Appraisals and Rates

122 East 42nd Street New York 17, N.Y.
3333 Book Tower Detroit 26, Mich.

HARRY J. KEELING

Consulting Engineer

Electrical—Mechanical—Corrosion

Investigations—Reports—Advisory Service
Mobile radio communication systems;
Special mechanical design problems;
Soil corrosion, Electrolysis,
Cathodic protection
of buried or submerged metal surfaces.

1718 Livonia Avenue Los Angeles 35, Calif.

ANGUS D. HENDERSON

Consulting Engineer

Water Supply and Sanitation

330 Winthrop St. Westbury, New York
210-07—29th Ave. Bayside, New York

ENGINEERING OFFICE OF CLYDE C. KENNEDY

Richard R. Kennedy Robert M. Kennedy

Investigation—Design
Water Supply Water Purification
Sewage and Waste Treatment
Water Reclamation

604 Mission St. San Francisco 5

HORNER & SHIFRIN

Consulting Engineers

W. W. Horner E. E. Bloss V. C. Lischer

Water Supply—Airports—Hydraulic Engineering—Sewerage—Sewage Treatment—Municipal Engineering—Reports

Shell Building St. Louis 3, Mo.

MORRIS KNOWLES INC.

Engineers

Water Supply and Purification,
Sewerage and Sewage Disposal,
Industrial Wastes, Valuations,
Laboratory, City Planning

Park Building Pittsburgh 22, Pa.

ROBERT W. HUNT CO.

Inspection Engineers

(Established 1888)

Inspection and Test at Point of Origin of Pumps, Tanks, Conduit, Pipe and Accessories

175 W. Jackson Blvd. Chicago 4, Ill.
and Principal Mfg. Centers

KOEBIG & KOEBIG

Consulting Engineers Since 1910

Investigations, Reports,
Designs and Appraisals
Water Supply & Water Treatment
Sewerage & Sewage Treatment
Municipal Engineering
Industrial Buildings

3142 Wilshire Blvd., Los Angeles 5, Calif.

LEGGETTE, BRASHEARS & GRAHAM

Consulting Ground Water Geologists

Water Supply — Salt Water Problems
Dewatering — Investigations
Recharging — Reports

551 Fifth Avenue — **New York 17, N. Y.**

Professional Services

METCALF & EDDY

Engineers

Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Airports — Valuations
Laboratory

Statler Building
Boston 16

THE PITOMETER ASSOCIATES, INC.

Engineers

Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Water Measurement & Special Hydraulic Investigations

50 Church Street — **New York**

Nussbaumer, Clarke & Velzy, Inc.

Consulting Engineers

Sewage Treatment—Water Supply
Incineration—Drainage
Industrial Waste Treatment
Appraisals

327 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

LEE T. PURCELL

Consulting Engineer

Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation

Analytical Laboratories

36 De Grasse St. — **Paterson 1, N. J.**

THE H. C. NUTTING COMPANY

Testing Engineers—Inspection Service
Foundation Investigation—Test Borings
Soil Mechanics—Sewage Flows—Analysis
Construction Control—Soil—Concrete
Bituminous Pavements—Water Waste Survey
Specifications—Consultations

4120 Airport Rd. — **Cincinnati 26, Ohio**

THOMAS M. RIDDICK

Consulting Engineer and Chemist

Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses

369 E. 149th St. — **New York 55, N.Y.**
MOtt Haven 5-2424

PARSONS, BRINCKERHOFF, HALL & MACDONALD

G. Gale Dixon, Associate

Civil and Sanitary Engineers

Water, Sewage, Drainage and Industrial Waste Problems.

Structures — Power — Transportation

51 Broadway — **New York 6, N.Y.**

RIPPLE & HOWE, INC.

Consulting Engineers

O. J. Ripple — V. A. Vaseen — B. V. Howe

Appraisals—Reports
Design—Supervision

Water Works Systems, Filtration and Softening Plants, Reservoirs, and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports

833—23rd St., Denver 5, Colo.

MALCOLM PIRNIE ENGINEERS

Civil & Sanitary Engineers

Malcolm Pirnie — Ernest W. Whitlock
Robert D. Mitchell — Carl A. Arenander
Malcolm Pirnie, Jr.

Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates

25 W. 43rd St. — **New York 36, N. Y.**

RUSSELL & AXON

Consulting Engineers

Civil—Sanitary—Structural
Industrial—Electrical
Rate Investigations

408 Olive St., St. Louis 2, Mo.
Municipal Airport, Daytona Beach, Fla.

Professional Services

ALDEN E. STILSON & ASSOCIATES
(Limited)
Consulting Engineers

Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports

245 N. High St. Columbus, Ohio

J. HOMER SANFORD
Consulting Engineer—Hydrologist
36 Years of Groundwater Investigation

Groundwater Development, Recharge,
Dewatering and Salt Intrusion
Analysis of Available Supply and Safe Yield
Litigation Reports and Testimony

1 Ascan Avenue Forest Hills 75, N.Y.

J. STEPHEN WATKINS
J. S. Watkins G. R. Watkins
Consulting Engineers

Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.

251 East High Street Lexington, Kentucky
Branch Office
901 Hoffman Building Louisville, Kentucky

SCHAEFER & WALTON
Consulting Ground-Water Hydrologists

Investigations, Reports, Advice
on
Ground Water Development, Induced
Infiltration From Surface Streams,
Artificial Recharge, Dewatering.

16 Leland Ave. Columbus 14, Ohio
Telephone AMherst 8-3316

WESTON & SAMPSON
Consulting Engineers

Water Supply and Purification; Sewerage, Sewage and Industrial Wastes Treatment. Reports, Designs, Supervision of Construction and Operation; Valuations.
Chemical and Bacteriological Analyses

14 Beacon Street Boston 8, Mass.

J. E. SIRRINE COMPANY
Engineers

Water Supply & Purification,
Sewage & Industrial Waste Disposal,
Stream Pollution Reports,
Utilities, Analyses

Greenville South Carolina

WHITMAN & HOWARD
Engineers
(Est. 1869)

Investigations, Designs, Estimates, Reports and Supervision, Valuations, etc., in all Water Works and Sewerage Problems

89 Broad St. Boston, Mass.

SMITH AND GILLESPIE
Consulting Engineers

MUNICIPAL UTILITIES
AND PUBLIC WORKS

Complete Engineering Services

JACKSONVILLE, FLORIDA

WHITMAN, REQUARDT & ASSOCIATES
Engineers Consultants

Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans
Supervision, Appraisals

1304 St. Paul St. Baltimore 2, Md.

STANLEY ENGINEERING COMPANY
Consulting Engineers

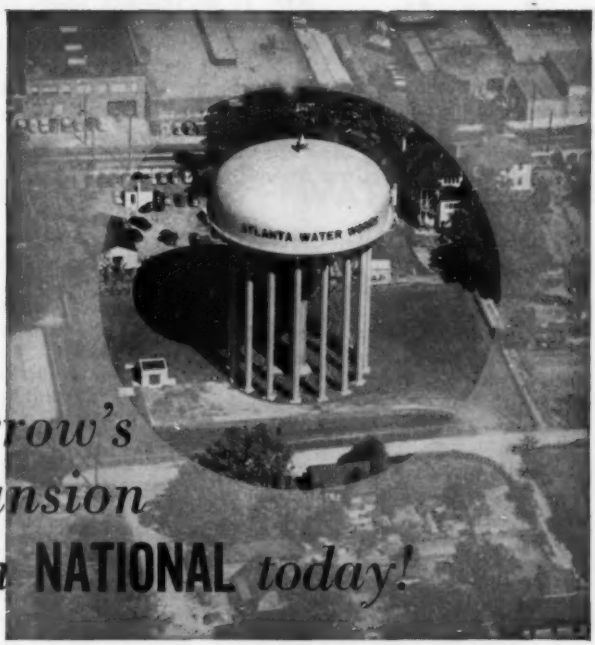
327 S. LaSalle Street Chicago 4, Illinois
Hershey Building Muscatine, Iowa

WILLING WATER
Public Relations Consultant

Willing Water cartoons available in low-cost blocked electrotypes and newspaper mats for use in building public and personnel good will.

Send for catalog and price list

American Water Works Association, Inc.
521 Fifth Avenue New York 17, N.Y.



For tomorrow's expansion call in **NATIONAL** *today!*

Like Atlanta, Ga., *you* too can meet tomorrow's increased water demands with *clean water mains.* When the coefficient of sections of Atlanta's 45 year old main dropped to a low of 44, Waterworks General Manager, Paul Weir ordered National cleaning. Results were outstanding. Water pressure and capacity doubled, giving better fire protection and higher water pressure to outlying sections.

Do as other leading cities have done—let *National* cleaning provide for tomorrow's expansion without capital expenditure today! We can prove that National cleaning is an investment—not an expense.

Write us today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

ATLANTA, GA; 333 Candler Building • BERKELEY, CALIF; 905 Grayson Street • DECATUR, GA; P. O. Box 385 • BOSTON, MASS; 115 Peterboro Street • CHICAGO; 122 So. Michigan Avenue • ERIE, PA; 439 E. 6th Street • FLANDREAU, S.D; 315 N. Crescent Street • KANSAS CITY, MO; 406 Merchandise Mart and 2201 Grand Avenue • LITTLE FALLS, N.J; BOX 91 • LOS ANGELES; 5075 Santa Fe Avenue • MINNEAPOLIS, MINN; 200 Lumber Exchange Building • RICHMOND, VA; 210 E. Franklin Street • SALT LAKE CITY; 149–151 W. Second South Street • SIGNAL MOUNTAIN, TENNESSEE; 204 Slayton Street • MONTREAL, CANADA; 2032 Union Avenue • WINNIPEG, CANADA; 576 Wall Street • HAVANA, CUBA; Lawrence H. Daniels, P. O. Box 531 • SAN JUAN, PUERTO RICO; Luis F. Caratini, Apartado 2184.

Condensation

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

CHEMICAL FEEDING, CONDITIONING, AND SEDIMENTATION

Demineralized Makeup for 1,250-psi Installation at East Millinocket Mill of Great Northern Paper Co. E. F. DAVIDSON. Trans. Am. Soc. Mech. Engrs., **78**:875 ('56). High makeup requirements for 1,250-psi boiler caused installation of coagulating plant and complete demineralization plant. River water contained appreciable amt. of org. matter. Lab. coagulation tests with various treating chem. showed that 60 ppm of $Al_2(SO_4)_3$, 10–16 ppm of alkali as NaOH, and 10–12 ppm of activated SiO_2 at pH of 6.2 resulted in good coagulation of suspended solids and reduced O demand and color to less than 5 ppm. This was later shown to be insufficient to prevent fouling of anion bed; this bed was cleaned up by use of NaCl soln. followed by NaOH soln. It was recommended that coagulation process be supplemented by chlorination and filtration through active C to remove balance of org. material. Change was made from reciprocating engines to turbines, thus removing oil contamination from steam. Condensate return lines were cleaned by use of several different Oakite solns. and alk. Na_3PO_4, so that condensate eventually showed less than 1 ppm of oil. With removal of oil films from condensate return lines, it was necessary to use neutralizing amine to raise pH of condensate to 8.5. Recent anal. of condensate samples shows avg. Fe content of 0.26 ppm.—*CA*

Conditioning of Water Improves Rapid Sand Filter Performance. H. C. CHANDLER. Wtr. Wks. Eng., **108**:312 ('55). In normal flocculation and sedimentation process for treatment of raw water prior to filtration on rapid sand filters, author emphasizes provision of adequate mixing facilities for chem., and use of tank large enough to allow detention period of 4 hr. Instances are given of other treatment applied at water works in N.Y. state to improve performance of rapid sand filters. At Albany, N.Y., disadvantages of too-short detention period have been overcome by addn. of lime to effluent from the sedimentation tank prior to rapid sand filtration. In this way small floc particles are disintegrated and formation of tight surface mat on filters prevented. Manganese removal is also facilitated by addn. of lime to settled water, with little or no increase in turbidity or color. At Gloversville, where raw water is soft and of extremely low alkalinity, limestone flour is added prior to alum for coagulation, and soda ash and sodium hexametaphosphate are added to filtered water in attempt to lessen corrosive properties of water. Presence of protozoan *Synura* in Albany water supply, particularly in winter months, gives rise to objectionable tastes. To overcome this, main impounding reservoir is treated with copper sulfate each autumn. Should organism still appear, activated carbon is applied prior to rapid sand filtration, and in event of delay in application of copper sulfate at reservoir, raw water is subjected to break-point chlorination.—*WPA*

Silica Removal From Water by Filtration Through Alkaline Materials. E. SCHUMANN. Mitt. Ver. Grosskesselbesitzer, **40**: 30 ('56). Very little SiO_2 is removed in lime process for water softening unless Mg salts are present. Calcined dolomite (half-burned) is suitable filter means for SiO_2 removal, but mole ratio $[(Mg)(OH)]/Mg(OH)_2$ should provide sufficient Mg. Ca ions in raw water sep. out as $CaCO_3$ and are continuously replaced by Mg ions so that total hardness of water is practically unchanged. Part of Mg is pptd. as $Mg(OH)_2$, carrying down proportionate amt. of SiO_2. pH of filtered water rises to 10–10.3 regardless of whether water is condensate or from lime softening, demineralizers, etc.

(*Continued on page 66 P&R*)

WORTHINGTON-GAMON

WATCH DOG WATER METERS

The meter used by thousands of municipalities in the U. S.

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WORTHINGTON-GAMON METER DIVISION

Worthington Corporation

296 SOUTH STREET, NEWARK 5, NEW JERSEY

OFFICES IN ALL PRINCIPAL CITIES

6 TIMES MORE THAN WE NEED

MODERNIZED **cast iron**

RAINFALL ...still not enough!

No secret to you that water is America's No. 1 Problem... that rainfall is largely wasted, unevenly distributed or polluted.

But does the public know it?

It's important that the great mass of the American people learn the facts. We're helping there.

Month after month our national advertising stresses the need for long range planning of water facilities; public support for realistic water rates; necessary water works financing; conservation by homeowner and industry.

Our aim... like yours... is to alert the public to the growing seriousness of water shortages... enlist their cooperation so that we—and our children—will be assured of a plentiful supply of water for all our needs.

CAST IRON PIPE

proved by Performance

Over a hundred years ago cast iron pipe mains were laid by more than 70 American utilities. They're still working efficiently.

Here's proof of cast iron pipe's dependability and longevity... its savings in maintenance costs and tax dollars.

Today's modernized cast iron pipe, centrifugally cast for greater strength and uniformity, is even more durable. Where needed, it can be cement-lined for sustained carrying capacity through generations of hard use.

When you specify pipe for your water system, remember: no other pipe can match cast iron's *proved* record of performance. It serves for centuries.

Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 122 So. Michigan Ave., Chicago 3, Illinois.

This rugged old cast iron water main, laid 125 years ago, is serving and saving tax dollars for the citizens of Detroit, Michigan.

CAST IRON

The Q-Check stencilled on pipe is the Registered Service Mark of the Cast Iron Pipe Research Association.

pipe FOR MODERN WATER WORKS

Fordin' Along...

Ancient Rome was supplied with about 92 million gallons of water a day by eleven aqueducts ranging in length from eleven to sixty miles. In spite of their skill and resourcefulness, as evidenced by magnificent arches to support the water channels, Roman engineers never mastered the ability to create conduits to carry water under pressure. So it was necessary to bridge the valleys even at tremendous effort and expense, resulting in a legacy of monuments to man's vision and energy which have endured over two thousand years.

(*Continued from page 62 P&R*)

This pH has no effect on SiO_2 removal. Increase in concn. of Mg ions required for Si removal and more rapid exchange of Ca ions by Mg ions can be secured by decreasing filter velocity, increasing thickness of calcined dolomite, warming water to 40–60°, or by increasing Mg-salt concn. of calcined dolomite. SiO_2, $CaCO_3$, and $Mg(OH)_2$ are deposited together within calcined dolomite in fine granular form, which can readily be washed out, restoring activity of mass. However, both grain size and wt. of calcined dolomite decrease with each cycle.—*CA*

The Use of an Uncovered Ion-Exchange Filter. I. A. Cherepennikov & P. P. Rumyantsev. Energetik. (U.S.S.R.), **4**:24 ('56). Steel and brass covers on ion-exchange filters show high deg. of corrosion during regeneration step. Plastic covers vary in brittleness and therefore in stability. Ceramic filters of Porolith type can be used. Distributing system is of concrete, and upper half of tube remains open. On concrete base are arranged 3 ceramic plates which are held in place by connecting angles to prevent dislodgement during regeneration cycle. Hydraulic resistance of system depends upon particle size of plates and of ion-exchange material.—*CA*

Guides for Selecting Chemical Feeders. P. A. Coffman Jr. J. Southwest Water Works, **37**:8 ('55). These are: operational requirements; storage capacity required; choose best available location, type of installation, and of feeder; select accessories desired; furnish complete information for manufacturer; and evaluate carefully proposals submitted.—*CA*

Instrumentation of a Demineralizing Plant. E. J. Tilly. Instruments and Automation, **28**:1532 ('55). Plant is described which produces 1 mgd of demineralized water and 7 mgd of clarified water from river

(*Continued on page 68 P&R*)

FREE

FORD SPECIAL METER TESTING BENCHES

offer High Efficiency

In many large meter shops the volume of testing justifies special equipment. The possibilities are worth investigating. Write for information.

THE FORD METER BOX COMPANY, INC.
Wabash, Indiana

FOR BETTER WATER SERVICES

FORD

(Continued from page 66 P&R)

water. Raw water is first screened; soda, clay, and alum are added, and then water is clarified in 2 2,500-gpm sludge blanket upflow reactors; large part of this clarified water (less than 5 ppm turbidity as SiO_2) is used as such, rest is treated in cation-exchange, then an anion-exchange unit. Water with cond. of less than 8 micromhos is produced. Extensive instrumentation results in reliable, continuous process. 2 improvements in instrumentation are needed; first, more accurate method of proportioning dry chemical feed to flow and secondly, good automatic method for detection when cation unit is exhausted.—*CA*

Flow Path Effect on Sedimentation. E. B. FITCH. Sewage and Ind. Wastes, **28**: 1 ('56). Reexamn. of theories of sedimentation. Validity of Camp's conclusion that long, narrow, rectangular tanks are superior in performance to radial flow tanks is questioned.—*CA*

FOREIGN WATER SUPPLIES —GENERAL

Some Aspects of Manganese Deposits in Water Conduits in the Eastern Part of the State (Eastern Belgium). G. VAN BENEDEN. Bull. centre belge étude et document (Liege) (Belg.), **27**:8 ('55). Deposits in water mains from Warche and Gileppe dams contg. mostly Mn_3O_4 or MnO_2 are due primarily to biol. action and only to certain degree to chem. reactions and adsorption. Deposit in steel main (pipe) of 2 m diam. leading from the Warche dam (at Bévercé) contained: water 87% of total wt., Mn_3O_4 55.57, Fe_2O_3 3.43, SiO_2 6.04, and loss on calcining 29% of dried deposit, and cellulose 1.61% of wet deposit (pectin and hemicellulose 0%). Deposit after 16 yrs. was approx. 16 mm thick and its sp. gr. was 0.6. van B. calcd. that out of 70 millions cu m of water passing annually through conduit, 0.35 cu mm of deposit was formed by each l of water.

(Continued on page 70 P&R)

LaMOTTE CONTROLS

have served the Water Works Engineer for more than 35 years.

Have you sent for the latest booklet on this helpful LaMotte Service?

***For example*—did you know that the LaMotte-Pomeroy Sulfide Testing Outfit determines accurately:**

• Total Sulfides • Dissolved Sulfides • Hydrogen Sulfide in Sludges and Solutions • Free Hydrogen Sulfide in Air and Gases? •

We will be happy to send full information on this and other LaMotte units used in the Water Works field.

LaMOTTE CHEMICAL PRODUCTS COMPANY

Dept. AWWA Chestertown, Md.

buy and use

CHRISTMAS SEALS

fight tuberculosis

Concrete Pressure Pipe is universally accepted for city water systems

as witnessed by its use in all major cities in the United States and Canada

Great supporting strength, high carrying capacity and long life make Concrete Pressure Pipe ideal for city water supply lines, transmission lines, and distribution mains.

Modern manufacturing plants are located so as to make Concrete Pressure Pipe available in all sections of the United States and Canada.

Member companies are equipped to manufacture and furnish concrete pressure pipe in accordance with established national specifications and standards.

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street
Chicago 1, Illinois

WATER FOR GENERATIONS TO COME

(Continued from page 68 P&R)

Water is mildly acidic and contains in certain cases even 10 times more Fe than Mn; however, Mn was selectively pptd. van B. thinks that *Leptothrix* bacteria oxidize Mn salts to Mn_3O_4, taking advantage of liberated energy (above bacteria also oxidize Fe salts to rust). Deposition of Mn in conduits can also be explained by fact that flocculation of Fe in mineral water in contact with air is much more rapid than is flocculation of Mn; ratio Fe:Mn is much higher in unflocculated water than in filtrate of that water after flocculation.—*CA*

Basis for a Program of Control of Pollution of the Waters of the State of Sao Paulo [Brazil]. E. R. YASSUDA. Arquiv. Hig. E. Saude Pub. (Sao Paulo), 7:169 ('53). In state of Sao Paulo, growth of cities and industrial expansion has brought progressive increase in poln. of natural waters. At same time, state pop. is using in larger scale same water it had used for years for drinking purposes, industrial activities, agriculture, recreation and navigation. It is legal right of federal government to control water poln. in country, having in mind predominance of sanitary aspects of problem and what is correspondingly established by federal constitution. State, however, can legislate in order to protect natural waters in areas under jurisdiction. Legislation is named suppletive or complementary, taking into account that it does not collide with federal legislation on subject. Several trials were made to control water poln. in state of Sao Paulo. In this work, author analyses causes of failures of previous trials and, at same time, proposes basis for rational soln. New statal law worked out with govt. support and collaboration of Technical Div. of San. Eng. of Sao Paul Eng. Institute is also presented. Technical division believes new law offers legal basis of program for protection of natural waters in state, taking into account actual organization of administration. Development of control program will

(Continued on page 72 P&R)

For Organic Iron and Color Removal—Algae Control—Regeneration of Iron Removal Filters—

Use

POTASSIUM PERMANGANATE

Supplied to industry and municipalities in various grades and meshes to fit the particular operation efficiently and economically in combating many water problems.

WRITE FOR QUOTATIONS

CARUS CHEMICAL COMPANY

Box JAW LaSalle, Illinois

MUNICIPAL SUPPLIES

No. 152

ESTABLISHED 1900—47 YEARS OF SERVICE

W.S. DARLEY & CO.

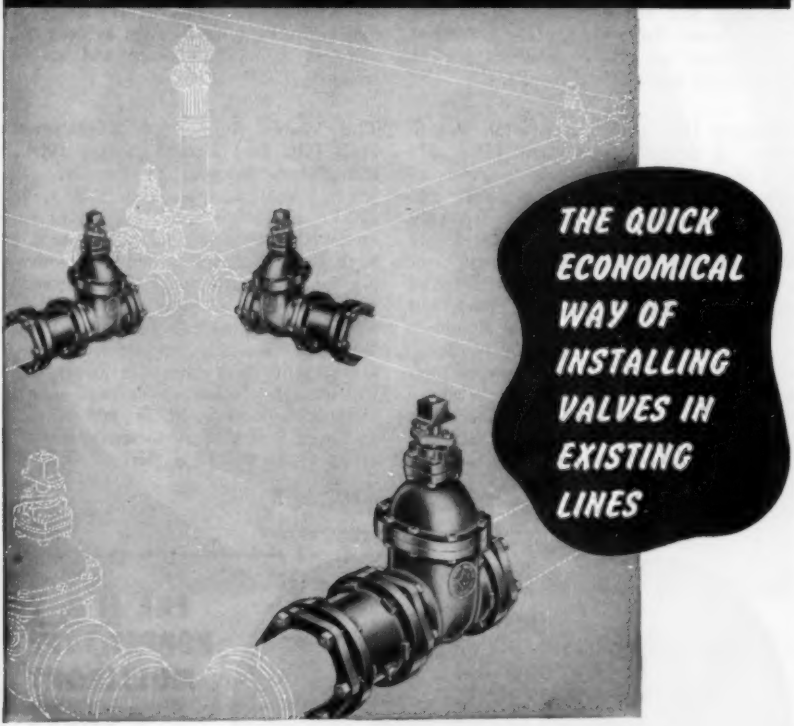
WRITE TODAY

For

100 PAGE CATALOG

W. S. DARLEY & CO. Chicago 12

SMITH CUT-IN VALVE AND SLEEVE



The Smith Mechanical Joint Cut-in Valve and Sleeve is truly the answer to the problem of installing gate valves in existing piping which can be relieved of pressure. The design reduces size of excavations, installation time and in-service cost to the minimum. Two substantial stop screws lock the Valve and Sleeve securely in place.

The Cut-in Valve and Sleeve can be installed on any standard class of cast iron pipe. Molded rubber gaskets fit into machined "Stuffing Box Type" joints, which are permanently leak proof. Smith Cut-in Valves are manufactured in compliance with the A.W.W.A. gate valve specification. Write for Bulletin MJ2.

55

FIRE HYDRANTS · VALVES SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

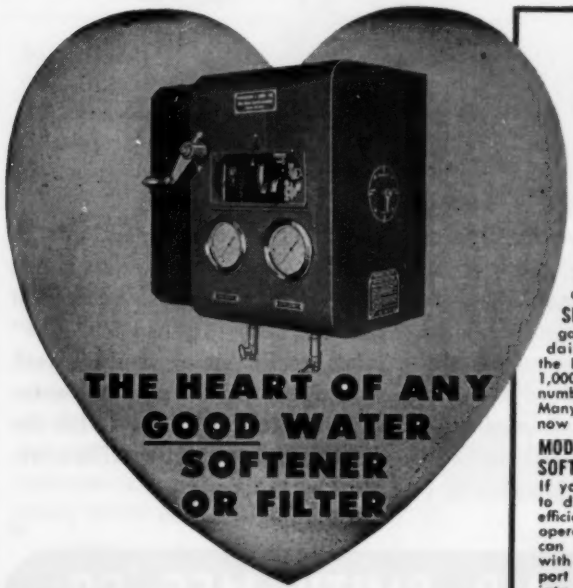
(Continued from page 70 P&R)

require exptl. installations and research. It will require, also, staff trained in public health to perform office and field duties. Same staff will study treatment processes applied to most diversified types of industrial wastes. State has good possibilities, present and future, to apply program.—*PHEA*

Darlington [Gt. Br.] Corporation Water Works. J. Brit. Wtrwks. Assn. (Br.), **37**: 133 ('55). Historical review is given of development of public water supplies and works in Darlington, where source of supply is soft, moorland water, sometimes deeply colored, of river Tees. Major alterations at water works in 1928 included replacement of slow sand filters by rapid sand filters, and water was coagulated with sodium aluminate and aluminium sulfate prior to filtration. Since that date, works have remained virtually unchanged but for addn. of more pumps and filters, constr. of weir over river Tees near intake, and increase in size and covering of Harrowgate Hill reservoir. Fluoridation of water supply is to be undertaken, as Darlington is one of 4 areas in Gt. Brit. selected by the Ministry of Health for fluoridation expts. It is also proposed that activated silica be used as coagulant in place of sodium aluminate and aluminium sulfate.—*WPA*

The Water Supply of Kingston-upon-Hull [Gt. Br.] From 1292 to 1954, and the Future Sources of Supply. T. H. Jones. Wat. & Wat. Eng. (Br.), **59**:161 ('55). Historical acct. is given of various attempts, each accompanied by new problems, that were made to augment water supply for Kingston-upon-Hull to remedy serious shortage of water over past 25 yr. Present source is chalk outcrop of Yorkshire Wolds and is solely dependent upon rainfall, hence giving most unreliable supply. Kingston-upon-Hull plant serves pop. of 400,000, maintaining supply of 25 gpd per capita. In future it is planned to obtain water from river Hull, which is derived from chalk

(Continued on page 74 P&R)



HUNGERFORD & TERRY, INC.
CLAYTON 5, N. J.

THE H & T
POPPET TYPE
MULTIPORT
VALVE

A masterpiece of workmanship and operating simplicity. Your choice of manual, semi-automatic, or fully automatic.

SERVICE — Many millions of gallons of water are treated daily by equipment using the H & T poppet valve. Over 1,000 are now in use and the number is rapidly increasing. Many of the original valves are now in use for over 10 years.

MODERNIZING OLD SOFTENERS AND FILTERS — If your equipment is too good to discard, yet too old to be efficient or too complicated to operate and control, these units can very often be equipped with H & T poppet type multiport valves — and be made into attractive and efficient water treating units.

Write for free information bulletin

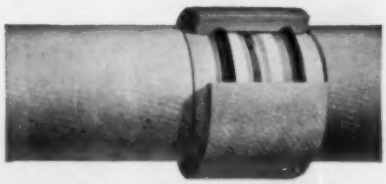
The pipe that's built for tomorrow

K&M "Century"® Asbestos-Cement Pressure Pipe slashes maintenance costs

Over the years, pumping costs are stabilized, maintenance is minimized with K&M "Century" Pressure Pipe. It is non-tuberculating, non-corrosive, non-electrolytic—its bore remains smooth and clean. "Century" Pipe is made of asbestos fiber and portland cement . . . two practically indestructible materials which assure long life.

And it's lower in initial cost, too! It's light in weight for easy, inexpensive transportation and handling, and even unskilled labor can lay it quickly in any kind of weather.

"Century" Pipe can save a community big tax dollars. Write for full information!

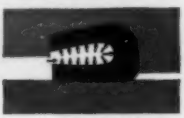


NEW K&M "FLUID-TITE"® COUPLING*

Crews can lay more pipe per hour in any kind of weather with K&M "Fluid-Tite" couplings.

*Patent applied for

Rubber rings compress to allow easy, quick entrance for pipe.



Pressure expands rings. Higher pressure means tighter seal.

KEASBEY & MATTISON COMPANY • AMBLER • PENNSYLVANIA

K&M Best in asbestos®

(Continued from page 72 P&R)

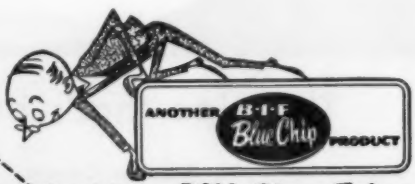
springs and has avg. flow of 100 mgd. New treatment plant will have capac. of 12 mgd and storage reservoir capac. will be 300 mil gal.—*WPA*

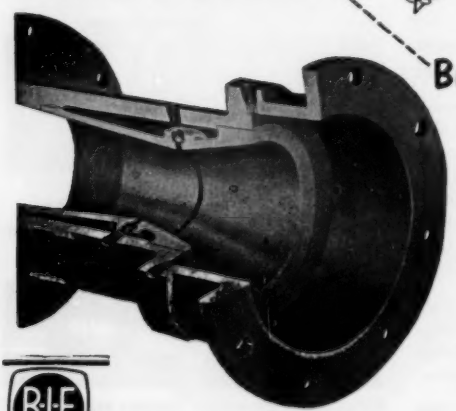
New Chemical Treatment of Water, South West Suburban Water Company [Gt. Br.]. J. Brit. Wtrwks. Assn. (Br.), **37**:155 ('55). In 1950, South West Suburban Water Co., with works at Egham, was empowered to abstract a max. of 9.5 mgd of water from Thames R., avg. intake being 7 mgd. Seasonal fluctuation in qual. of water, with heavy load of suspended solids present at times of flood, and increased load to be filtered necessitated introduction of a sedimentation process. 20 upward-flow sludge-blanket sedimentation tanks were installed at works, coagulation being effected by aluminium sulfate and sodium silicate modified with sodium bicarbonate in proportion of 30 ppm silicate to 2 ppm bicarbonate. Details are given of tank constr. and chem. feed arrangements. After sedimentation, water passes to primary and secondary rapid sand filters, and is then super-chlorinated and dechlorinated with sulfur dioxide. Sedimentation has satisfactorily removed color and turbidity from Thames R. water and has also improved its bact. qual.—*WPA*

Stevenage Development Corporation Water Undertaking [Gt. Br.]. J. Brit. Wtrwks. Assn. (Br.), **37**:115 ('55). Designated area of Stevenage New Town, including industrial estate, and old Stevenage, to be supplied with water by Stevenage Development Corp. Water Undertaking lies mostly in river Lea drainage basin, a small part being in that of river Ouse. There is almost complete absence of surface water. Details are given of existing water supply prior to 1950, when new undertaking came into being. This was inadequate to meet demands of New Town. Approval was given for new developments to supply up to 65 gpd per head by sinking 3 boreholes of 36-in. diam. to approx. depth of 340 ft at

(Continued on page 76 P&R)

When To Use





Builders DALL Flow Tubes

- Use Dall Tubes when you need compact, minimum-cost installations: (average laying length only 1½ times line size).
- Use Dall Tubes when you need sustained metering accuracy: (smooth tapered throat is self-scouring, dimensionally stable).
- Use Dall Tubes when you can't afford head loss: (highest pressure recovery of any velocity-increasing differential producer).
- For complete details write for Bulletin 115-L1. Builders-Providence, Inc., 365 Harris Ave., Providence 1, R. I.

B-I-F INDUSTRIES
PROVIDENCE, RHODE ISLAND
B-I-F METERS FEEDERS CONTROLS

THE NATION'S No. 1 SOURCE

for dependable pipe line equipment

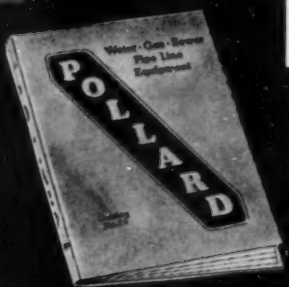
Like hundreds of Pollard customers, you'll find it mighty pleasant and convenient to order pipe line equipment from Pollard.

Here, under one roof and listed in one comprehensive catalog, are all the time and money saving products you need on the job. Each is guaranteed for dependability, economy. Each is backed by Pollard service.

MANHOLE CUSHION

DIAPHRAGM PUMPS

JOINT RUNNERS

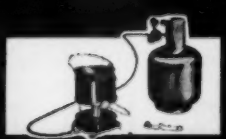


PIPE CUTTERS

MAKE POLLARD YOUR SOURCE FOR PIPE LINE EQUIPMENT. ORDER FROM POLLARD CATALOG 26.

M-SCOPE PIPE FINDER

CALKING TOOLS



MELTING FURNACE

PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

PIPE LINE EQUIPMENT

Place your next order with POLLARD

If it's from POLLARD . . . it's the Best in Pipe Line Equipment

NEW HYDE PARK • NEW YORK

Branch Offices: 1064 Peoples Gas Building, Chicago, Illinois
333 Candler Building, Atlanta, Georgia

(*Continued from page 74 P&R*)

Whitehall, 3½ mi. south-east of designated area. Design of these works allows for pumping station, from which water will pass over aerator to remove excess carbon dioxide, into equalizing and contact tank where super-chlorination will be given followed by dechlorination with sulfur dioxide. After 25-min contact period, water will pass into second equalizing tank. Treated water is pumped through 24-in. rising main to storage reservoirs and water tower at Pin Green, on the higher ground in the north-east of the area. The first section of the reservoir, of 2-mil gal capacity, has been completed, and constr. of second section of similar capac. and of water tower is in hand. Water is supplied by gravity from reservoirs through ring main system. Supplementary source of ground-water supply at Sacombe, 6½ mi. south-east of Stevenage, intended for Stevenage, is now to be developed by Harlow Development Corp., but supplies will be available for Stevenage should those from Whitehall prove inadequate. Phys., chem. and bact. anals. of Whitehall water show it to be satisfactory for drinking purposes, with pH value of 7 and total hardness, mainly temporary, of 254 ppm. Arrangements have been made for installation of water-softening plant at Whitehall, should approval be given.—*WPA*

Oxygen Content of White Sea Water [U.S.S.R.]. E. N. CHERNOVSKAYA. Doklady Akad. Nauk., S.S.S.R. (U.S.S.R.), **97**: 911 ('54). From 1949 to 1953, the O_2 of White Sea waters was 1.26–6.56 mg/l, but was mostly 2–3 mg/l. This level is 5–6 times that of waters of Barents Sea and very similar to that of Azov and Caspian Seas which contain many fish. Highest values were found in littoral waters in south where rivers empty. Lowest values were found 50 m. below surface to bottom of sea. Highest values usually were found in Jun. after heavy discharges of fresh water from rivers in late May and early Jun. O_2 content gradually decreases during summer with slight increase in Sep. followed by decrease during fall and winter. Practically no change in waters were found below 50-m. level.—*CA*

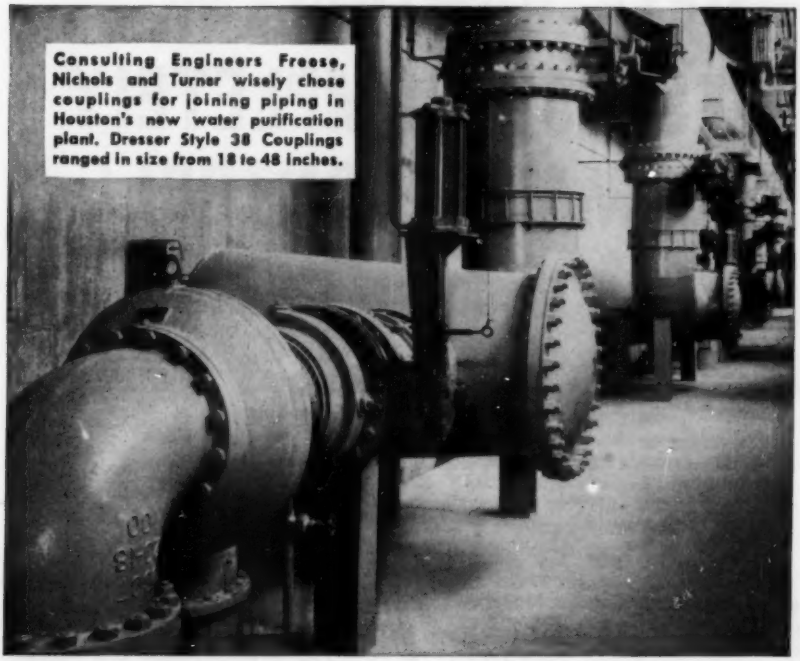
ELEVATED STEEL TANKS

● **Elevated Steel Tanks for water supply, ranging from 5,000 to 2,000,000 gallons—ranging from standard hemispherical self-supporting bottom to spherical tank on tubular tower.**

Correctly built in accordance with AWWA specifications. Send us your inquiry, stating capacity, height to bottom and location. Established 1854. Write for *Tank Talks*.

R. D. COLE MANUFACTURING CO.
COLE
NEWNAN, GEORGIA

NEW SIMPLEX FILTER



Consulting Engineers Freese, Nichols and Turner wisely chose couplings for joining piping in Houston's new water purification plant. Dresser Style 38 Couplings ranged in size from 18 to 48 inches.

Houston solves piping problems for good

Steel pipe and Dresser Couplings provide flexible installation, easy accessibility

Houston's new water purification plant, a part of the San Jacinto River Water Project, integrates some of the latest developments in industrial design with time-proved principles of municipal water treatment.

The new plant reflects the wise use of steel pipe and mechanical couplings where weight, price and greater flexibility are important factors.

Consulting Engineers Freese, Nichols and Turner of Houston specified Dresser Couplings teamed with steel pipe "to provide for expansion and contraction of long runs of pipe, to provide for flexibility in the installation and possible future dismantling of large pipe assemblies, and to connect steel pipe to concrete hydraulic structures."

Whenever you join pipe—especially near valves or any type of mechanical installation—provide easier installation and permanence with safe, sure Dresser Couplings.

Regardless of vibration or expansion-contraction, the resilient gaskets in Dresser Couplings hold bottle-tight for life. This built-in flexibility, particularly important between rigid flanges, serves to prevent piping strain from reaching valve casings and working parts. Result: greater efficiency, longer life.

Installation with Dresser Couplings requires only a wrench, is fast and simple. You can forget time-consuming procedures because Dresser Couplings compensate for slight misalignments, facilitate installation of set, rigid equipment on piping. These couplings also permit easy entrance into lines for maintenance or repair of equipment.

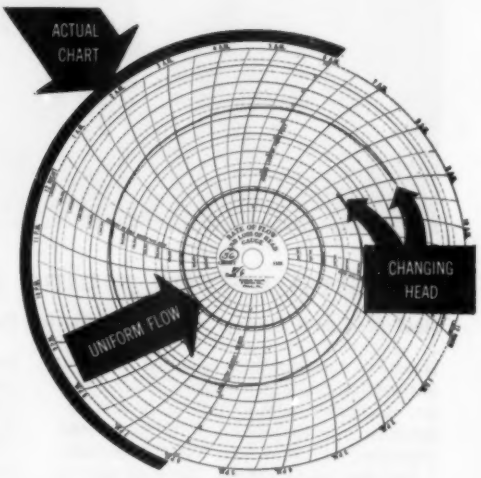
No other method of pipe joining provides all these proved advantages. Make sure you have foolproof, leakproof Dresser Couplings on your next water, sewerage or industrial project. For complete information, call your local piping supply house or write Dresser Manufacturing Division, Bradford, Pa. Sales offices in: New York, Philadelphia, Chicago, S. San Francisco, Houston, Denver, Toronto and Calgary.

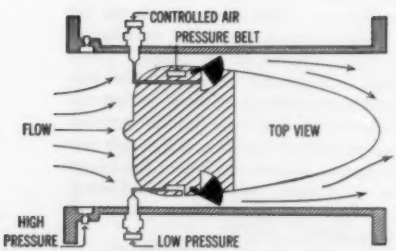
ONE OF THE DRESSER INDUSTRIES

NEW SIMPLEX FILTER RATE CONTROLLER GIVES YOU COMPLETELY PNEUMATIC CONTROL!

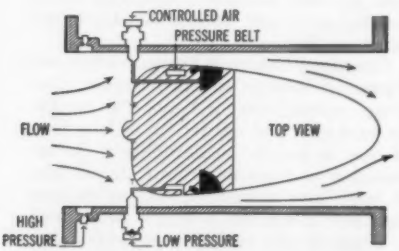
Amazing Modulair® Controller responds fast...closes tight

Here's proof that the new Simplex Modulair Filter Rate Controller responds instantly to changes in filter head, holds flow at desired rate...automatically! In chart from Modulair installation No. 2, head changes from 4′ to 7′ while rate forms almost perfect circle at the set 275,000 gpd.

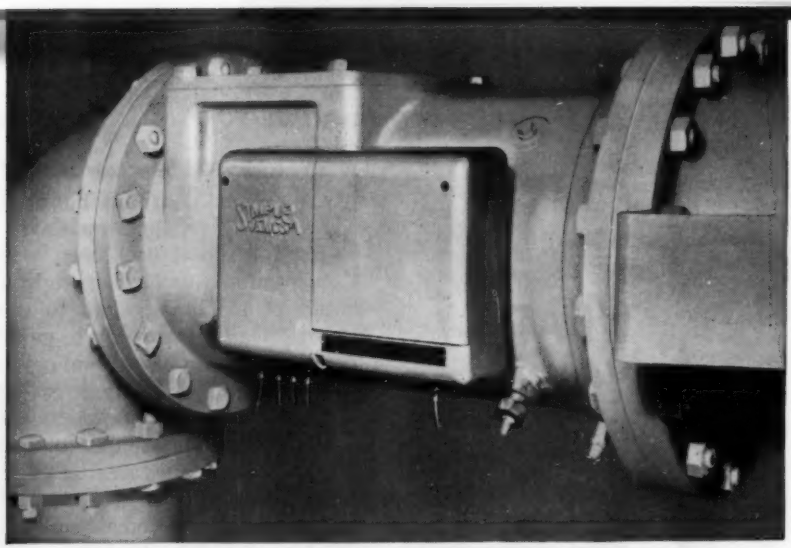




How Modulair works! Pipe-like casting with annular Venturi throat houses streamlined inner body with corded-rubber modulator (black) that expands and retracts pneumatically to control flow. When head is low at start of run, modulator expands automatically to hold flow at set rate.



As filter head loss rises, flow tends to decrease . . . and change the Venturi differential. Sensitive Modulair compensates by instantly retracting the pneumatic modulator, maintaining a constant head-loss value through the combined filter and controller, automatically keeping flow at set rate!



Compact . . . easily installed Modulair is only two to three pipe diameters long! It fits wherever a piece of pipe can fit . . . in any position, horizontal or vertical . . . simplifying pipe gallery layout. High-grade, cast iron Modulair comes in 4" to 24" standard pipe sizes with corrosion-resisting fittings. Cord-inserted rubber throttling element that's as tough as a truck tire has given 30 years' wear in accelerated life-tests.

Accuracy! In 4 years of field performance, Modulair charts show an accuracy in filter control that exceeds today's most exacting demands. This high degree of control extends for wide ranges of head loss and flow rates, including complete, tight shut-off! And there's no drift at end of run.

Longer filter runs! Modulair combines a low head-loss, annular Venturi measuring element with a streamlined throttling element. This new design offers so little resistance to flow that you get longer filter runs, big savings in wash water!

Minimize maintenance! With Modulair's new design, there's no place for air to accumulate . . . no place for sand to lodge and interfere with accuracy. Throttling element, the only moving part inside pipeline, is non-corrosive rubber. Pneumatic poise element is simple, rugged. There are no line valves, no pilot valves, no pistons, no valve shafts, no stuffing boxes to pack!

Lower first cost! Modulair's low head loss means lower operating head requirements . . . permits vertical compression in plant design and lower costs in plant construction.

Completely pneumatic! No intermediate hydraulic steps! No pilot valves! No hydraulic cylinders! Air loading pressure is applied *directly* to the flow controlling element.

Automatic filter operation! Modulair works with control systems of any type to give you remote rate control or master pneumatic control that's fully automatic.

Technical bulletin! For full details on Modulair, write for Bulletin 950. Simplex Valve & Meter Company, Dept. JA-10, 7 East Orange Street, Lancaster, Penna.

Accurate instruments and controls for over 50 years

SIMPLEX®

VALVE AND METER COMPANY

WHAT'S YOUR CHOICE?

A trickle or a gusher? Ace bets it's a gusher (maximum free-flow through your water system.) If you're not enjoying this healthy condition, call an ACE-man to give you the facts on ACE's new power-system of water main cleaning. Even though trouble is not critical, a call now may save you important time and money when that day arrives.

A CALL IS ALL!

Chestnut 1-2891, Kansas City, Mo., for an ACE-engineer . . . free estimates and surveys. No obligation, of course.

Ace PIPE CLEANING, INC.

GENERAL OFFICE: 3513 EAST 18th ST., KANSAS CITY, MO.

PHONE CHestnut 1-2891

(*Continued from page 52 P&R*)

A prophet without honor, indeed, is the weatherman these days. As a matter of fact, he's been wrong so much more often than right of late that people have begun to count on that. Had he anything to gain by the misinformation he so seemingly always issues, we'd be ready to call for an investigation. But he doesn't and we can only suppose him an exbookie, who became ex because he went broke. Our heart really bleeds for him when we don't want to break his neck.

One possible explanation for the degeneration of his forecasts has been the atom bomb, and, although that factor has been pretty thoroughly poohpoohed by eminent meteorologists and nuclear physicists from fission to fallout, we have been happy to hear no less a scientist than General Electric's Dr. Irving Bengelsdorf, a follower of Nobel laureate Irving Langmuir, argue that the atom *can* change the weather. Explaining his belief in terms of Langmuir's theory of divergent phenomena—that is, in terms of indeterminate events due to a single happening—Dr. Bengelsdorf has made a real case for his conclusion in the Jul. 7 issue of the *Saturday Review*. Not having followed the Bengelsdorf dialectics quite 100 per cent, we aren't certain whether one of the indeterminate events might not be the freezing of water in bird baths in Bergen County, N.J., when the weather bureau reported a minimum temperature of 41°F. Actually, this phenomenal divergence, which was reported by the Bergen *Record* last May, involved not only the bird bath ice and the weatherman's thermometer, but the thermometers of most residents in the area, which, undoubtedly because they were affected by the frozen bird baths, registered in the 20's.

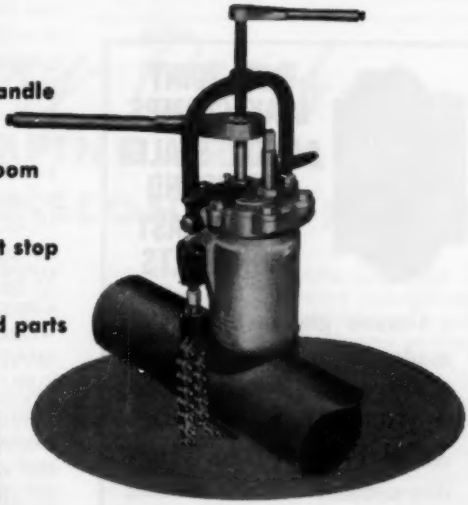
(*Continued on page 82 P&R*)

WANT THE BEST?

HAYS MODEL B

Aluminum Alloy Tapping Machine

- Designed for the man in the ditch
- A third less weight to handle
- Requires less time
- Requires less working room
- Easier to operate
- No disassembly to insert stop
- Positive grip on main
- Renewable bearings and parts
- Complete with chest



Your HAYS distributor or our representative will be glad to demonstrate the Model B . . . or write to us about one for a trial on the job by your own men.

Join the A. W. W. A. HAYS is one of the eleven Charter Members of the Manufacturers Section of the American Water Works Association.

HAYS®

WATER WORKS PRODUCTS

HAYS MANUFACTURING CO.

ERIE, PA.

(Continued from page 80 P&R)

Logical or not, the Bengelsdorf hypothesis is not likely to make any great impression on the majority of the weatherman's customer-critics, who are more interested in accuracy of information than adequacy of explanation. As a result, many have turned to other than meteorological data as a basis for their prophecy. Over in Britain, for instance, Harry Boon, night watchman at the Cleethorpes water works, bases his forecasts on the behavior of the gnats and swallows and, as proof of the accuracy of his technique, has a silver cup, awarded him by the grateful city fathers of the resort town of Cleethorpes upon his outdoing the official weather bureau in a month of competitive forecasting last August. Then, back home in Philadelphia, Ralph Tyler of the American Water Works Service Co. and Garry Flinn of the *Evening Bulletin* are vying for the title of premier rain caller. The Flinn system, checked over a 2-year period of record, has a 90.2 per cent record of accuracy in predicting rain within 24 hr, although it is based solely on the time of washing of the Flinn family car. The Tyler technique, which claims 89.1 per cent accuracy, has a considerably broader base, extending its time checks to shoeshines, lawn sprinkling, and the first-day wearing of new or newly cleaned suits, as well as auto wash. And, of course, there are always Aunt Hester's corns, Colonel Oglethorpe's San Juan Hill leg, and our own picnic and golf plans that rate as more or less sure indications of bad, if not all, weather.

Actually, although we are quite willing to take some of these informal and not entirely scientific predictions into consideration, we are not yet ready to give up completely on the weatherman, particularly in view of the availability of the type of equipment which the US Geological Survey has just enlisted to aid in processing its river gage-height charts automatically. "SURWAC" is what USGS has named its new electronic computer—"SURWAC" for Surface Water Automatic Computer. "MAMWAC" is what the weatherman obviously needs—"MAMWAC" for Meteorological and Manmade Weather Automatic Computer —to add the meteorological facts now assembled and all such influences as the efforts of cloud-seeders, the tests of atom bombs, and the Flinn-Tyler series, and come up with an answer in rain or shine. It's just about time the weather bureau realized that the only way to make a good prophet these days is to use a machine.

(Continued on page 84 P&R)

BELL JOINT LEAK CLAMPS

GASKET SEALER COMPOUND

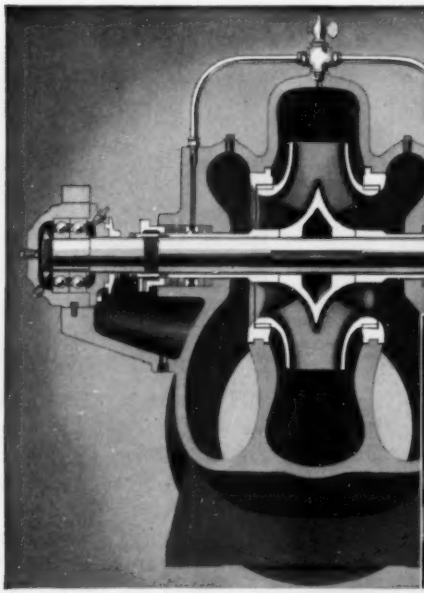
C-I-60 CAST IRON BOLTS

Carson glands and bolts made of corrosion-resistant C-I-60 cast iron—last as long as cast iron pipe. Glands accommodate variations in pipe dimensions, insure uniform compression of rubber gasket.

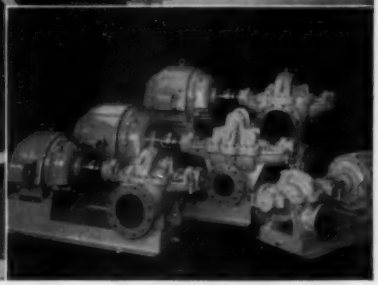
Write for information

H. Y. CARSON COMPANY

1221 Pinson St. Birmingham, Ala.



Cross Section Type M Pump. This construction is used, with minor variations, in all sizes 4" and larger.



Group of Double Suction Pumps ready for installation in municipal water works.

Worry-Proof

YOUR PUMPING PROBLEMS with WHEELER-ECONOMY PUMPS

This cut-away section of a Wheeler-Economy Type "M" Pump shows engineering that means around-the-clock, around-the-calendar performance . . . peace of mind for the men in charge. Longer life and less maintenance work results from these important features . . . The method of supporting the rotor between outboard bearings with end-thrust practically eliminated . . . horizontally split casing with all pipe connections in lower half so that rotating parts can be removed without disturbing connections or pump alignment . . . Inlet designed to reduce leakage and friction losses . . . Double-bearing construction provides for longer packing life . . . Low pressure stuffing boxes . . . Wearing parts readily renewable.

To insure correct application for your municipal or industrial project, Wheeler-Economy offers specialized engineering service as well as a wide selection of pump sizes and cases. Write for CATALOG A-1052.

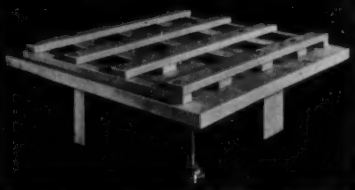
WE-512

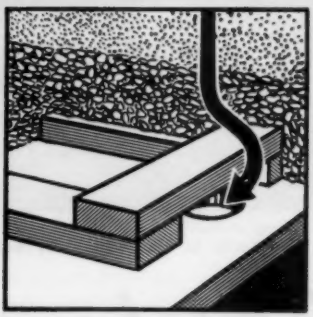
WHEELER-ECONOMY PUMPS

C. H. WHEELER MANUFACTURING CO., ECONOMY PUMPS DIVISION
19TH AND LEHIGH, PHILADELPHIA 32, PA.

TRANSITE FILTER BOTTOMS

Cut Your Filtration Costs





NON-CLOGGING PORTS

Transite filter bottoms are specially designed so that the ports cannot be blocked by gravel, closed by expansion, or enlarged. The flow remains constant and continuous and the backwash uniform. Highly practical filter bottom easily removed for inspection and quickly relaid.

The construction is strong—durable—and simple. Transite filter bottoms have been designed and tested to withstand a load of 5,000 lbs. per sq. ft., insuring a safety factor of *over* 4X. Field assembly requires a screwdriver and about five minutes per plate.

Write For Literature

FILTRATION EQUIPMENT CORPORATION

271 HOLLENBECK ST.
ROCHESTER 21, N. Y.

(*Continued from page 82 P&R*)

Jack J. Hinman Jr., Iowa City, Iowa, former AWWA president, died Jul. 26, 1956, while visiting his daughter at Orleans, France. He was 68. Born at Indianapolis, Ind., in 1888, he received an A.B. from Butler College in 1911 and an M.S. from the University of Iowa in 1915. After serving in World War I, he became assistant professor of epidemiology at the University of Iowa and chief of the water laboratory division of the state hygienic laboratory. From 1921 to 1938 he was associate professor of sanitation and taught related courses in the college of engineering at the university. Returning to service in World War II, he retired in 1948 with the rank of colonel and began his career as a full-time consulting engineer. In that capacity, he was frequently employed by government agencies and traveled extensively abroad.

An Honorary Member of AWWA (joined in 1915), Col. Hinman was vice-president in 1929, president in 1930, and director in 1931. The Iowa Section nominated him for a Fuller Award in 1952 "in recognition of his tireless efforts on behalf of the Association; and for his far-reaching contributions to the practice of water purification in the Americas, the Philippines, and the Far East." His

(*Continued on page 88 P&R*)

TRINITY VALLEY

for all CAST IRON WATER WORKS FITTINGS

Available On Order

AWWA Standard Bell Spigot Watermain Fittings—24 through 36 inch.
Ring Tite Fitting 3" thru 12"

Available Immediately From Stock

AWWA Approved Short Body and Mechanical Joint Watermain Fittings—2 through 12 inch.

AWWA Standard Bell Spigot Watermain Fittings—2 through 24 inch.

TRINITY VALLEY IRON AND STEEL CO.

Phone PE 7-3141 Fort Worth, Texas P. O. Box 804

Allis-Chalmers Helps Increase WATER to meet increasing needs of Niteroi, Brazil

Across the bay from Rio de Janeiro, the busy water-front city of Niteroi and its suburban areas needed more and better water to meet growing industrial and metropolitan requirements.

Untreated water was furnished from protected reservoirs — top capacity was 4500 gpm for almost 300,000 population.

Because of this, a new water system was installed, including a complete treatment plant and reservoir, with a direct-fall supply to the city in potential capacity of 16,000 gpm —an increase of over 250%. At present the system is putting out 9500 gpm, at an average 100 lb pressure, pending improvements in city mains and sewer system.

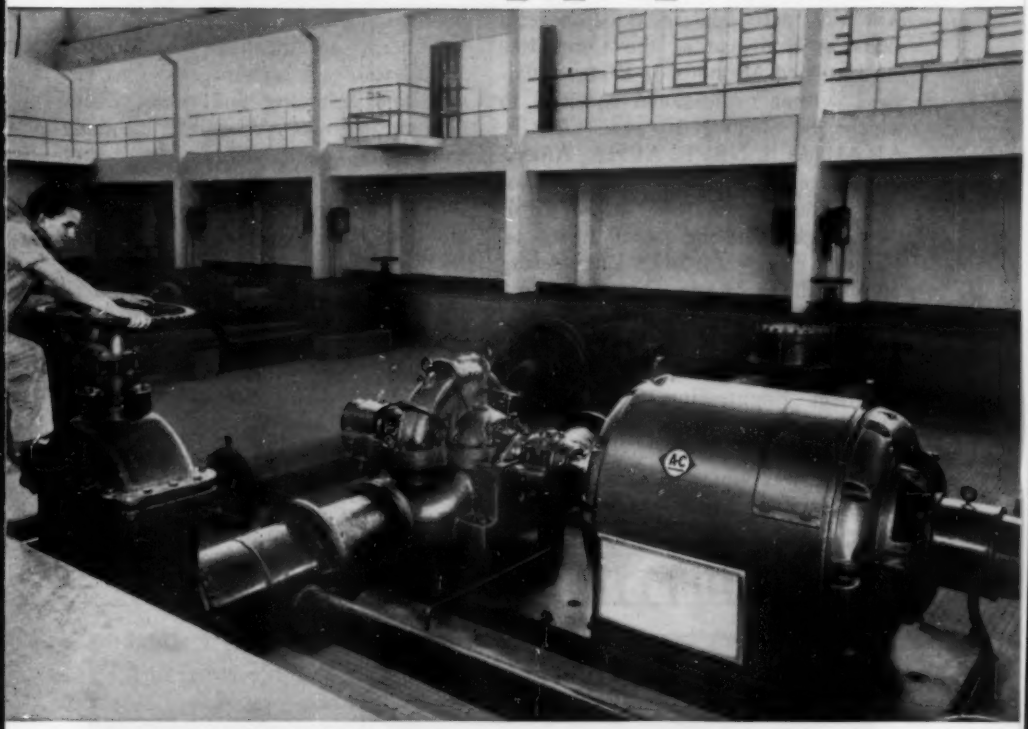
Two pumping stations supply Niteroi: Imunana, a new site on the river; and Laranjal, handling water from the mountains. Allis-Chalmers pumps, motors and control, installed and operating at both stations, furnish the greatly increased amount of water needed.

When YOUR CITY plans expansion or modernization, do as progressive communities all over the world are doing—call your nearest A-C office or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin. A-4950

Allis-Chalmers control lineup at Laranjal Station features three Type HARS-70 starters. Starters at Imunana Station are identical, used with Allis-Chalmers 500-hp synchronous motors.

ALLIS-

Equipment
Water Supply 250%



Three Allis-Chalmers 16 by 14-inch Type SI pumps, rated 7926 gpm, 295-ft head, are driven at 1200 rpm by Allis-Chalmers 800-hp, drip-proof, end-shield bearing synchronous motors. Laranjal Station is pictured—installation at Imunana is similar.

Exterior view of Laranjal Station. This contemporary building contains pumping units and operation offices. Modern housing units built at each station accommodate operating personnel.

Allis-Chalmers Builds the World's Largest Range of Equipment for Public Works

Pumps; motors, *Texrope* drives, control; switchgear, substations, transformers; butterfly valves; steam turbine-generator units, condensers, hydraulic turbines and generators, engine-generator units; blowers, compressors, vacuum pumps; dryers, screens, mills, sifters; tractors, graders, scrapers, motor wagons, power units.

Texrope is an Allis-Chalmers trademark.

CHALMERS

A-C ALLIS-CHALMERS

(Continued from page 84 P&R)

AWWA activities included several years as chairman of the Committee on Standard Methods of Water Analysis. Other professional societies to which he belonged were ASCE, AIChE, ACS, NSPE, APHA, American Society for Engineering Education, Inter-American Assn. of Sanitary Engineers, Society of American Military Engineers, Iowa Engineering Society, Iowa Waste Disposal Assn., and Iowa Public Health Assn.

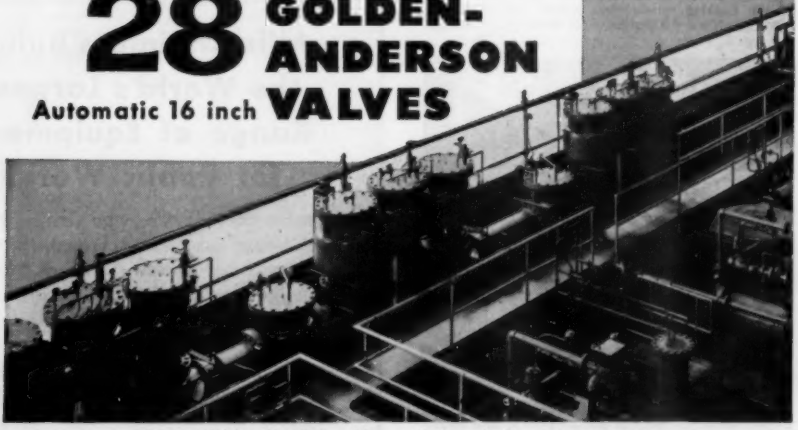
William Paterson, founder of the Paterson Engineering Co., London, England, died Aug. 9, 1956, after a brief illness. He was 82. Born in 1874, he was educated in Edinburgh. In 1902, after 6 years with a firm of paper mill engineers, he founded his own company to specialize in water treatment. During his career he was an innovator of such processes as excess-lime softening and ozone disinfection, and was responsible for many other significant advances in water treatment and allied fields. He also developed the well known Anderson air raid shelter, presenting its patent to his country. For his services, he was knighted in 1944. He retired as chairman of the company in 1955.

A Life Member of AWWA (joined in 1924), Sir William was also honored by the Institution of Water Engineers and the Royal Society of Health. His outstanding qualities served as a pattern and stimulus to those who had the privilege of being in contact with him throughout his life.

(Continued on page 90 P&R)

At the Bryant Street Pumping Station in Washington, D. C.
"The most modern pumping station in the world today"

28 GOLDEN-ANDERSON
Automatic 16 inch VALVES



4-page folder describing this installation gladly sent on request.
GOLDEN-ANDERSON VALVE SPECIALTY CO., 1221 Ridge Ave., Pittsburgh 33, Pa.

Masterpiece
OF PRECISION ENGINEERING

Maximum REVENUE,
MINIMUM Upkeep..
enduring accuracy
through the years.

CALMET

MANUFACTURED BY WELL MACHINERY & SUPPLY CO., INC.
FORT WORTH, TEXAS

(Continued from page 88 P&R)

Langdon Pearse, sanitary engineer of the Metropolitan Dist. of Greater Chicago, died Jul. 20, 1956, at the age of 79. Born at Boston, Mass., in 1877, he held an A.B. from Harvard (1899) and a B.S. in civil engineering (1901) and an M.S. in sanitary science (1902) from Massachusetts Inst. of Technology. After several years' experience in the water works field in various parts of the country, he joined the Chicago sanitary district in 1909 as assistant engineer, becoming successively division engineer and (in 1921) sanitary engineer, the position he held at the time of his death. In this post, he made notable contributions to the field of large-scale sewage treatment methods and plant design and operation.

A Life Member of AWWA (joined in 1913), Mr. Pearse was also one of the founders of FSIWA and was active in committee work for that organization, as well as for APHA and ASCE. Other professional societies to which he belonged were American Inst. of Consulting Engineers, Institution of Civil Engineers (England), Institution of Sanitary Engineers (England), Engineering Inst. of Canada, Western Society of Engineers, New England Water Works Assn., and American Academy of Arts & Sciences.

E. G. Ritchie, retired engineer of water supply for the Melbourne & Metropolitan Board of Works, Australia, died Jul. 23, 1956, at the age

(Continued on page 94 P&R)

AA QUALITY

For Public Water Fluoridation

Sodium Silicofluoride—98%

(Dense Powder)

Sodium Fluoride—98%

(Dense Powder or Granular)

Meets AWWA specifications

White or tinted blue
Minimum of dust in handling
Minimum of storage space

Available in bags and drums

The AMERICAN AGRICULTURAL CHEMICAL Co.

50 Church Street, New York 7, N. Y.

Get all the facts on TRANSMISSION PIPE... and you'll specify ALCO electric welded steel pipe

Consider these advantages in terms of your needs:

Fact #1 **STRENGTH** – Alco electric welded steel pipe is unaffected by vibration, has maximum resistance to shock and overloading due to earth movement and washouts. Can be supported on piers at 40-ft centers to span marshes and ravines.

Fact #2 **DURABILITY** – Alco steel pipe has long life, estimated up to 75 years. Withstands normally damaging force or impact through flexibility and strength.

Fact #3 **ECONOMY** – First cost of Alco electric welded steel pipe is low. Installation cost reduced by long lengths, light weight. More strength against bursting per dollar than other type of transmission pipe.

Fact #4 **EFFICIENCY** – Smooth, high-gloss tar-enamel inside surface gives maximum rate of flow, minimum friction loss.

Fact #5 **ADAPTABILITY** – Electric welded steel pipe can be transported over rough terrain without breakage, can be installed under water, in mud, sand, across ravines and on steep slopes without special care.

Fact #6 **MANY JOINING METHODS** – Alco electric welded steel pipe joints may be welded, flanged or Dresser-coupled. Can be joined to be leakproof under pressure conditions ranging from vacuum to thousands of pounds per square inch of water, air, gas or steam.

Fact #7 **WIDE SELECTION** – Alco electric welded steel pipe sizes, wall thickness and section lengths give you, in effect, a custom-tailored pipe. Special sections are available.

Ask your nearest Alco sales office for a copy of "*Alco Electric Welded Steel Pipe For All Type Of Installations,*" or write P. O. Box 1065, Schenectady 1, N. Y.

ALCO **ALCO PRODUCTS, INC.**
New York

...and not abandon our land

"There are mountains in Attica which can now keep nothing . . . but which were clothed, not so very long ago, with fine trees producing timber...while the country produced boundless pasture for cattle . . ."

As early as 300 B.C., when Plato thus lamented a tragedy of exhausted natural resources, there was little left of Attica's fertility — only insects crawling about the *"sites of extinct water supplies."* A lesson 2000 years old, to be heeded if we would escape the fate of Attica.

And the first logical step in vital water conservation is to replace flat, waste-conducive rates with Badger Metering.

The demand for water is at its peak in our history. All classes of users compete for more and *more*. A 75% increase in consumption is expected by 1975. In some areas the situation is already critical.

Curtailing waste with Badger Meters — fairly apportioning the responsibility and accounting for water use — is not only a sound investment in your community's future, but essential to its very survival.

The time to act is now — while there's still some water left to save! Write today for information on Badger Meters, or to arrange for a representative to call.

Badger Water Meters

Badger Meters have conserved it for 50 years

BADGER METER MFG. CO. MILWAUKEE 45, WISCONSIN

(Continued from page 90 P&R)

of 85. From 1908 until his retirement in 1936, he was in full charge of all construction, maintenance, and administration for the Melbourne water supply, and served as an adviser on many other water projects throughout Australia. Since 1936 he had acted as consultant for both national and local agencies concerned with water supply and flood prevention.

An Honorary Member of AWWA, which he joined in 1912, Mr. Ritchie was also a founder of the Institution of Engineers (Australia), which awarded him the Russell Memorial Medal, and a member of the Institution of Civil Engineers (England).

Thomas A. Cole, bacteriologist and former superintendent of the Poughkeepsie, N.Y., water filtration system, died May 28, 1956, at his home in that city. He was 72. Born at Poughkeepsie in 1884, he joined the city water works in 1906, where he became one of the first persons in the country to practice chlorination. Since his retirement as superintendent 6 years ago, he had been conducting a water analysis laboratory.

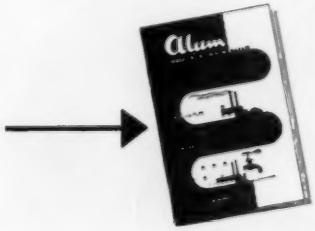
Mr. Cole joined AWWA in 1935 and served on its purification plant standards committee for several years. He was also active in APHA, as well as in civic affairs.

Kenneth S. Watson, consultant on water management and waste control for General Electric Co., has been appointed engineer adviser to the US delegation to the World Health Assembly in Geneva, Switzerland.

Depend on Cyanamid's **ALUM** for 6 good reasons

1. It feeds uniformly, without trouble, in solid or liquid form.
2. It has a wide pH range for effective coagulation.
3. It forms floc rapidly.
4. It gives maximum adsorption of suspended and colloidal impurities.
5. It causes minimum corrosion of feeding equipment.
6. It is available in granular form or in the new easy-to-use liquid form.

For a copy of "Alum—Commercial Aluminum Sulfate," please send us your name and title on company stationery—and would you also mention where you saw this offer?



CYANAMID

AMERICAN CYANAMID COMPANY

Heavy Chemicals Department

30 Rockefeller Plaza, New York 20, N. Y.

In Canada: North American Cyanamid Limited, Toronto & Montreal

COMPLETE..VIOLENT..INSTANT..UNIFORM

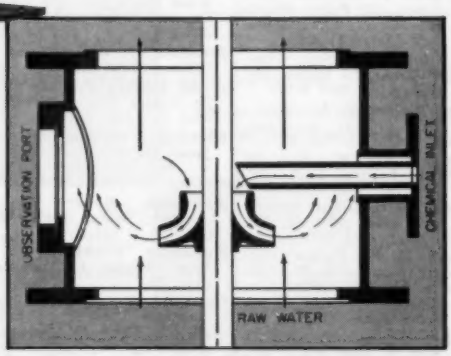
American HOMOMIX CHEMICAL MIXING

without a Mixing Tank

2-stage Homomix

The HOMOMIX gives instantaneous, violent, and uniform mixing of one or more chemicals, or gases, with water. *Immediate, total diffusion*—the most important factor for the efficient and economical addition of chemicals or gases—is obtained *without the use of a mixing tank!* For new plants it eliminates the necessity for costly mixing tank construction; for existing plants it can be effectively used to improve treatment.

The HOMOMIX, in one or more stages, is installed in, and forms part of, the piping. Diffuser impellers rotate in blending chambers and discharge directly across the flowing-through stream. Each chamber has one or more chemical inlet connections and a transparent plastic observation port through which the mixing action is visible. A lifting stage can be provided for additional head, if required. *Write for Technical Supplement HM and Bulletin 300.*



Our staff of Sanitary Engineers will cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

AMERICAN WELL WORKS

IN OUR 68TH YEAR
112 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

NEW MEMBERS

Applications received Aug. 1–31, 1956

Aeschliman, Ralph N., Contractor, Jessie Storrer, Archbold, Ohio (Jul. '56)*M*

Allan, Herrick D., Supt., Water Dept., 107 Cherry St., Swanton, Ohio (Jul. '56)

Angele, Gustave John, Plant San. Engr., Union Carbide Nuclear Co., Box Y, Bldg. 9739, Oak Ridge, Tenn. (Jul. '56) *P*

Anoka Water Dept., C. Rudolf Johnson, City Mgr., Anoka, Minn. (Munic. Sv. Sub. Jul. '56) *D*

Bartoletti, Fred A., Mgr., Southwestern Pennsylvania Water Authority, Box 1029, Clarksville, Pa. (Jul. '56) *M*

Baugh, Richard S., Branch Mgr., Harris Pump & Supply Co., Charleston, W.Va. (Jul. '56) *PD*

Bell, James G.; *see* Kirkham, Michael & Assocs.

Bright, Marshall, Jr., Supt., Lyman Printing & Finishing Co., Lyman, S.C. (Jul. '56) *MRP*

Bryant, Edward Andem, Engr., Hazen & Sawyer Engrs., 3333 Book Tower, Detroit, Mich. (Jul. '56) *P*

Burgess, Jan Kelso, Asst. Sanitary Engineer, US Public Health Service, 300 C St., S.W., Washington, D.C. (Jul. '56) *RP*

Buskirk, Robert F., Supt., Newton Water Works, 24 Hudson St., Homer, N.Y. (Jul. '56) *MPD*

Chambers, Robert G., Sales Repr., Hareo Corp., 16901 Broadway, Cleveland, Ohio (Jul. '56) *R*

Clevenger, James W., Supt. of Public Works, Imperial, Calif. (Jul. '56) *MPD*

Connolly, Joel I., Mutual Security Mission to China, APO 32, San Francisco, Calif. (Jul. '56)

Currington, H. W., Partner, Marvin Turner Engr., 305 W. 11th St., Austin, Tex. (Jul. '56)

Dailey, Charles, Foreman, Water Dept., Great Falls, Mont. (Jul. '56)

Demyan, Joe G., Sales Repr., Buffalo Meter Co., 2917 Main St., Buffalo, N.Y. (Jul. '56)

Dewing, Albert, Supt., Water Dept., Box 304, Bridger, Mont. (Jul. '56) *D*

Dickinson, City of, Peter J. Pfau, Supt., Water & Sewer Depts., Dickinson, N.D. (Munic. Sv. Sub. Jul. '56) *MRPD*

Doty, Arl, Contractor, North Vernon, Ind. (Jul. '56)

Dowson & Dobson, Ltd., E. F. Laschinger, Director, Johannesburg, South Africa (Assoc. M. Jul. '56)

East Greenville Borough Council, Willard S. Hoffman, Operator of Water Works, East Greenville, Pa. (Corp. M. Jul. '56) *MPD*

Eck, Russel E., Chief, Stream Pollution Sec., State Board of Health, Indianapolis, Ind. (Jul. '56)

Fairborn, City of, L. W. Yowler, Supt., Water Service, City Bldg., Fairborn, Ohio (Corp. M. Jul. '56) *MD*

Fisher, Lowell, Foreman, Water Dept., Great Falls, Mont. (Jul. '56)

Fried, Daniel Harold, Tech. Supervisor, Peter J. Schweitzer, Inc., 182 Cornelson Ave., Jersey City 4, N.J. (Jul. '56) *P*

Frykman, P. L., Water Supt., Arrowsmith, Ill. (Jul. '56) *MPD*

Gorey, J. Allen, Mfer.'s Repr., 272 La Salle Ave., Buffalo, N.Y. (Jul. '56) *D*

Granato, Henry, Water Controlman, Navy Public Works Center, 505 Camp Asan Agana 8, Guam (Jul. '56) *MRPD*

Gregg, Herman Hestal, Jr., San. Engr., Jones & Cleckley, 816 Cotton Lane, Augusta, Ga. (Jul. '56) *PD*

Hinkle, Mark L., Asst. Water Works Supt., City Hall, Marion, Ind. (Jul. '56) *M*

Hoffman, Willard S.; *see* East Greenville (Pa.) Borough Council

Hubbard, William, Mgr., Canadian-British Engineering Consultants, 513 Barrington St., Halifax, N. S. (Jul. '56) *MRPD*

Jacobson, Frank S., Civ. Engr., Water Dept., Rm. 903, Civic Center, San Diego, Calif. (Jul. '56) *MRD*

Johnson, C. Rudolf; *see* Anoka (Minn.) Water Dept.

Kiehl, Harold T., Plant Operator, La Grange Water Dept., Brookfield, Ill. (Jul. '56)

Kirkham, Michael & Assocs., James G. Bell, Gen. Mgr., 618½ St. Joe St., Rapid City, S.D. (Corp. M. Jul. '56) *MRPD*

Knowlton, Robert B., Chief Operator, Water Dept., Warren, Ohio (Jul. '56) *P*

Kuenstler, Frank Lloyd, Sales Repr., Mueller Co., Decatur, Ill (Jul. '56)

Lallande, Peter H., Gen. Mgr., Statewide Valve & Fitting Co., 1725 W. Culver St., Phoenix, Ariz. (Jul. '56)

Laschinger, E. F., Director, Dowson & Dobson, Ltd., Johannesburg, South Africa (Jul. '56)

Lauriault, Pierre, Engr., Lauriault & Lauriault, 863 Couvent, Montreal, Que. (Jul. '56) *PD*

Leitch, James M., Asst. Supt., Water Works, 453 W. 12th Ave., Vancouver 10, B.C. (Jul. '56) *MD*

Le May, Chris O., Supt., Water Dept., 208 N. Broadway, De Pere, Wis. (Jul. '56) *MRPD*

Lewis, Richard Albert, Chemist, Elizabethtown Water Co., 22 W. Jersey St., Elizabeth, N.J. (Jul. '56) *P*

Lockwood, John V., Chief Water Pumping Plant Engr., Dept. of Water Supply, 10100 E. Jefferson, Detroit, Mich. (Jul. '56) *M*

Ludlow, Willard J., Plant Mgr., Clark's Summit Water Co., 1 Zimmerman St., Clark's Summit, Pa. (Jul. '56) *M*

Lynch, K. P., Mgr., Water Works Board, Opelika, Ala. (Jul. '56)

Macy, George R., Master Plumber, A. Macy & Son, 2112 W. Iowa St., Chicago 22, Ill. (Jul. '56)

Mathis, Wilburn Deward, Sales Repr., Southern Meter & Supply Co., 1300 W. Lee St., Greensboro, N.C. (Jul. '56) *D*

McCord, Robert K., Sales Repr., R. D. Wood Co., Public Ledger Bldg., Philadelphia, Pa. (Jul. '56)

McCullough, John Paul, Salesman, Neptune Meter Co., 1565 Stanford Pl., Charlotte, N.C. (Jul. '56) *MD*

Melone, Gerald, Sales Engr., Dresser Mfg. Div., 101 S. Airport Blvd., South San Francisco, Calif. (Jul. '56) *MD*

Milbert, Howard W., Mgr., Culligan Soft Water Service, 1001 Marie Ave., South St. Paul, Minn. (Jul. '56) *RP*

North, Carl McCarty, Engr., Paul J. Kleiser & Assocs., Terre Haute, Ind. (Jul. '56)

Payne, Lloyd H., Mgr., Clarion Water Co., Clarion, Pa. (Jul. '56) *MRPD*

Petersburg Water Co., James Stephenson, Water Works Supt., City Hall, Petersburg, Ind. (Corp. M. Jul. '56) *MRPD*

Pfau, Peter J.; *see* Dickinson (N.D.)

Polzin, Richard W., Salesman, Longview Lime Corp., Woodland, Ala. (Jul. '56) *P*

Reynoldsburg, Village of, Clayton I. Tucker, Supt., Water Works, Reynoldsburg, Ohio (Corp. M. Jul. '56) *MD*

Roarick, Raymond H., Mueller Co., 219 Greenwich Blvd., San Antonio, Tex. (Jan. '56)

Sailer, John R., Counsel, Elizabethtown Water Co., Elizabeth 4, N.J. (Jul. '56) *R*

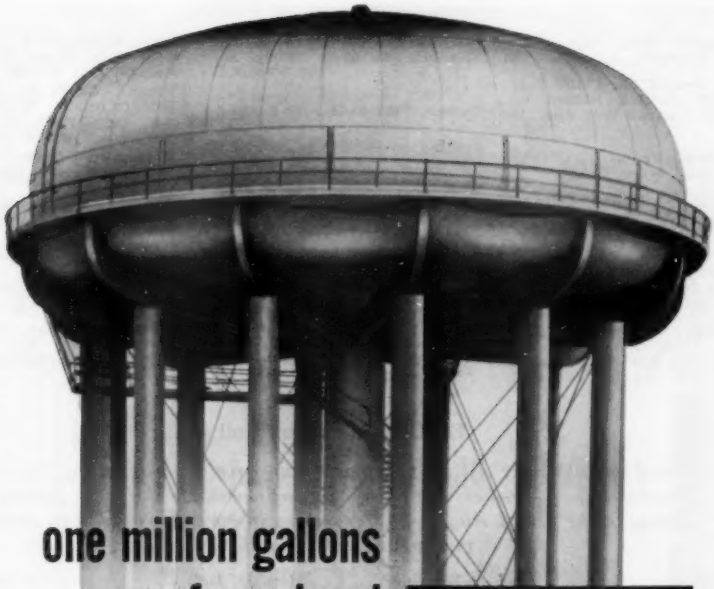
Scoyne, Billey, Supt., Public Utilities Com., Blenheim, Ont. (Jul. '56) *M*

Shaw, Frank A., Mgr., B-I-F Industries, Inc., 2302 Main St., Buffalo, N.Y. (Jul. '56) *D*

Simon, Peter Klaus, Hydr. Engr., Centriline Corp., 140 Cedar St., New York, N.Y. (Jul. '56) *D*

Snyder, Richard F., Local Mgr., Ohio Water Service Co., Struthers, Ohio (Jul. '56) *M*

(*Continued on page 98 P&R*)



one million gallons of overhead water storage for rapidly expanding fayetteville, north carolina

Capacity ..... 1,000,000 Gal.
Tank Diameter ..... 86 Feet
Height of Columns....111 Feet
Range of Head.....25 Feet
Overall Height (approx.).....146 Feet

consulting engineer
wm. c. olsen & assoc.
raleigh, north carolina

Steel Standpipes, Steel Reservoirs, Elevated Water Tanks, Water Spheres, Filtration and Purification Units for General Water Supply & Fire Protection Systems

Write for Catalog H_2O

HAMMOND IRON WORKS

WARREN and BRISTOL, PA. • PROVO, UTAH • CASPER, WYO. • BIRMINGHAM, ALA.

sales offices: new york 20 • boston 10 • arlington, va. 9 • cincinnati 2 chicago 3 • los angeles 57 • greenville, s. c. • sapulpa, okla. buenos aires • lima • mexico, d. f. • port-au-prince • cairo

(Continued from page 96 P&R)

Sox, James Cecil, Supt., Water Dept., Lexington, S.C. (Jul. '56)

Spence, Gerald M., Chem. Engr., Monolith Portland Midwest Co., Box 878, Laramie, Wyo. (Jul. '56) *P*

Stephenson, James; *see* Petersburg (Ind.) Water Co.

Stuppnig, Anthony Vincent, Plant Operator, Iron Mountain Filtration Plant, Iron Mountain, Mich. (Jul. '56) *MP*

Swartout, George D., Dept. Mgr., Hughes Supply, Inc., Orlando, Fla. (Jul. '56)

Swedberg, Kenneth C., Asst. Supt., Mech. Equipment, Water Dept., 1900 Rice St., St. Paul 17, Minn. (Jul. '56) *D*

Tomlinson, C. C., Dist. Mgr., Southern Meter & Supply Co., 1300 W. Lee St., Greensboro, N.C. (Jul. '56) *D*

Tucker, Clayton I.; *see* Reynoldsburg (Ohio)

Tufford, Norman E., Village Mgr., Holly, Mich. (Jul. '56) *MRPD*

Watson, Gordon L., Supt., Water Works, City Hall, Marion, Ind. (Jul. '56)

Wenner, Edwin D., Mgr., Mountain City Water Co., 113 N. Nice St., Frankville, Pa. (Jul. '56) *MRPD*

Wert, Edward, Mayor, City Hall, Marion, Ind. (Jul. '56)

Westbrook, Eugene R., Mgr., Berwick Water Co., 106 E. 2nd St., Berwick, Pa. (Jul. '56)

Whaite, Raymond S., Mgr., Canawacta Water Supply, Susquehanna, Pa. (Jul. '56) *MRPD*

Williams, Clyde E., Jr., Secy.-Treas., Clyde E. Williams & Assocs., Inc., 312 W. Colfax, South Bend, Ind. (Jul. '56) *MPD*

Willows, Jim, Owner, Glacier Water Co., Hungry House, Mont. (Jul. '56) *MP*

Winter, Joseph N., Engr., Dept. of Public Utilities, Tacoma, Wash. (Jul. '56) *D*

Yowler, L. W.; *see* Fairborn (Ohio)

Yuen, George A. L., Civ. Engr., Board of Water Supply, Honolulu, Hawaii (Jul. '56) *PD*

Zippro, Cornelius, Jr., Sales Engr., Dresser Mfg. Div., 41 Fisher Ave., Bradford, Pa. (Jul. '56)

EMGAMY Honor Roll

Listed below are the AWWA members who have contributed to "Every-Member-Get-A-Member Year" by getting members for the Sections shown, in the period Aug. 1–31. Numbers in parentheses indicate more than one member enrolled.

California
Brown, W. C.
Byrne, D. W.
Driggs, R. J.

Canadian
Kline, J. D.
Stanley, W. E.

Chesapeake
Harris, R. R.

Florida
Wells, S. W.

Illinois
Johnson, D. W.

Indiana
Gordon, Jack (5)
Griswold, H. S.
Kleiser, P. J.

Kentucky-Tennessee
Applebaum, S. B.

Michigan
Johnson, R. L.
Moulton, E. Q.
Troglia, L. D.
Wallace, W. M.

Montana
Chestnut, B. H. (2)
Clarkson, A. W.
Spencer, J. W., Jr.

New Jersey
Pleibel, A. F.
Radcliffe, J. L.

New York
Austin, R. W.
Clark, R. S.
Houlihan, D. J.
Squier, D. C.

North Carolina
Young, E. G. (3)

North Central
Thompson, L. N.

Ohio
Beatty, C. E.
Carty, J. V.
Moses, J. E., Jr. (2)
Price, J. P.

Pacific Northwest
Benedetti, A. J.

Pennsylvania
Murdoch, W. J.
Patterson, J. W.

Rocky Mountain
Turre, G. J.

Southeastern
Biddle, C. C.
Kelley, I. C.
Kolb, T. A.
Russell, Sherman (2)

Southwest
Jackson, L. A.
Sanders, R. N.

West Virginia
Schrader, G. P., Jr.

US Territorial
Wicke, H. A.
Woodall, B. W.

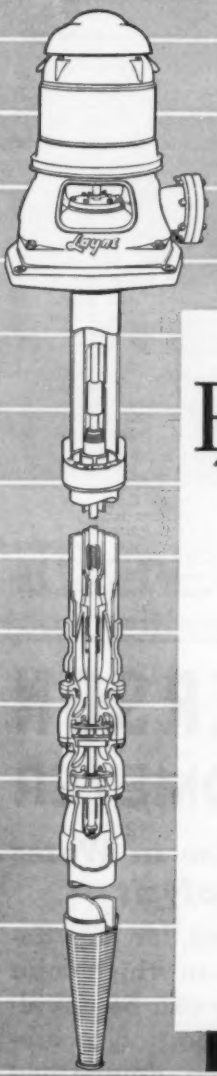
Filter Sand and Gravel

Well Washed and Carefully Graded to Any Specification.
Prompt Shipment in Bulk or in Bags of 100 lb. Each

Inquiries Solicited

NORTHERN GRAVEL COMPANY

P. O. Box 307 **Muscatine, Iowa**



Rx Making sick wells...WELL!

Layne research men have scored major successes in diagnosing and curing sick wells. Frequently a sick well can be saved at nominal cost.

This Layne service is further proof that it is always wise first to *"ask the man from Layne."*

LAYNE
& BOWLER, INC.
MEMPHIS
General Offices and Factory

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

Water Wells • Vertical Turbine Pumps • Water Treatment

Index of Advertisers' Products

Activated Carbon:
Industrial Chemical Sales Div.
Permutit Co.

Activated Silica Generators:
Omega Machine Co. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Aerators (Air Diffusers):
American Well Works
Carborundum Co.
General Filter Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

Air Compressors:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Morse Bros. Mchy. Co.

Alum (Sulfate of Alumina):
American Cyanamid Co., Heavy Chemicals Dept.
General Chemical Div.

Ammonia, Anhydrous:
General Chemical Div.
John Wiley Jones Co.

Ammoniators:
Fischer & Porter Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Co., Inc.

Brass Goods:
American Brass Co.
M. Greenberg's Sons
Hays Mfg. Co.
Mueller Co.

Calcium Hypochlorite:
John Wiley Jones Co.

Carbon Dioxide Generators:
Infilco Inc.
Walker Process Equipment, Inc.

Cathodic Protection:
Electro Rust-Proofing Corp.
Harco Corp.

Cement, Portland:
Monolith Portland Midwest Co.

Cement Mortar Lining:
Centriline Corp.

Chemical Feed Apparatus:
Cochrane Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Omega Machine Co. (Div., B-I-F Industries)
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Ross Valve Mfg. Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Chemists and Engineers:
(See Professional Services)

Chlorination Equipment:
Builders-Providence, Inc. (Div., B-I-F Industries)
Everson Mfg. Corp.
Fischer & Porter Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Chlorine Comparators:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Chlorine, Liquid:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Clamps and Sleeves, Pipe:
James B. Clow & Sons
Dresser Mfg. Div.
M. Greenberg's Sons
Mueller Co.
Rensselaer Valve Co.
Skinner, M. B., Co.
A. P. Smith Mfg. Co.
Smith-Blair, Inc.
Trinity Valley Iron & Steel Co.

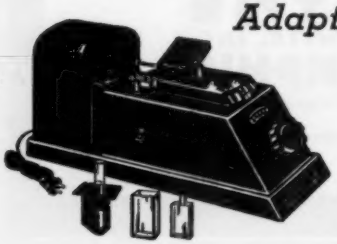
Clamps, Bell Joint:
James B. Clow & Sons
Dresser Mfg. Div.
Skinner, M. B., Co.

Clamps, Pipe Repair:
James B. Clow & Sons
Dresser Mfg. Div.
Skinner, M. B., Co.
Trinity Valley Iron & Steel Co.

Clarifiers:
American Well Works
Chain Belt Co.
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

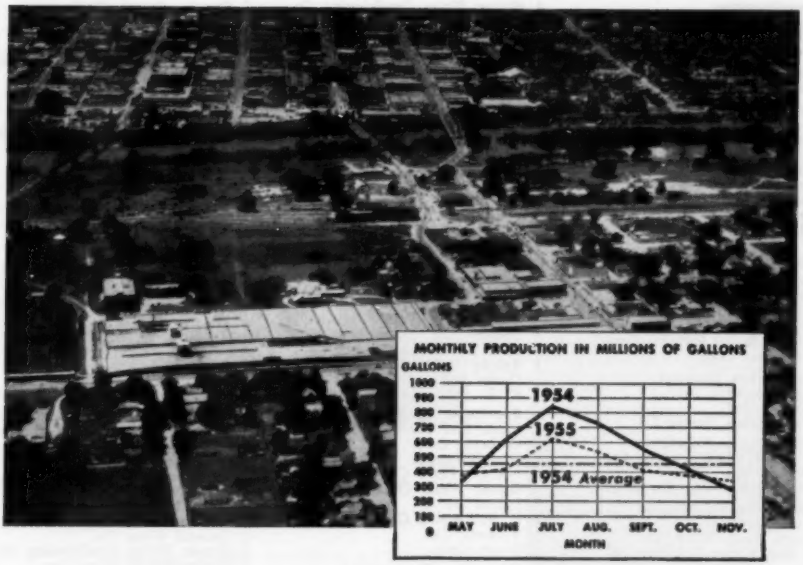
KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

KLETT MANUFACTURING CO.
179 EAST 87th STREET · NEW YORK, N. Y.



ALOXITE® underdrains handle double load without difficulty in Waco, Texas

Peak loads during dry spells really tax Waco's water system. At these times the filters handle up to 4 GPM per sq. ft.

In July, 1954, for instance, water consumption jumped from the year's average of 448 MG to 842 MG per month. Despite this 87% increase in demand there were no operating difficulties.

Much credit for being able to meet such abnormal requirements is given to the ALOXITE® aluminum oxide porous underdrains. These were installed in new filters in 1951.

Since then, several related events have occurred. Population has grown from 84,000 to 110,000. Water consumption has reached 14.7 MGD from 10.0 MGD. And mudballs and upset beds are but a memory for the plant operators. Uniform, ample backwashing is now an established and vital phase of operation.

The City of Waco is to be commended for its foresight in providing equipment to assure adequate water supply, even during peak demand periods. Mr. Curtis Harlin is Superintendent of Water and Sewage, while Mr. W. J. Biederman is Plant Superintendent. J. J. Rady Company, Fort Worth, Texas were Consulting Engineers.

CARBORUNDUM

Registered Trade Mark

Dept. 0106, Refractories Division

The Carborundum Company, Perth Amboy, New Jersey

Condensers:
Alco Products, Inc.
Allis-Chalmers Mfg. Co.
United States Pipe & Foundry Co.

Contractors, Water Supply:
Layne & Bowler, Inc.

Controllers, Liquid Level, Rate of Flow:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Foxboro Co.
General Filter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.

Copper Sheets:
American Brass Co.

Copper Sulfate:
General Chemical Div.
Phelps Dodge Refining Corp.
Tennessee Corp.

Corrosion Control:
Alco Products, Inc.
Calgon, Inc.
Philadelphia Quartz Co.

Couplings, Flexible:
DeLaval Steam Turbine Co.
Dresser Mfg. Div.
Philadelphia Gear Works, Inc.

Diaphragms, Pump:
Dorr-Oliver Inc.
Morse Bros. Mchy. Co.
Southern Pipe & Casing Co.

Engines, Hydraulic:
Ross Valve Mfg. Co.

Engineers and Chemists:
(See Professional Services)

Feedwater Treatment:
Allis-Chalmers Mfg. Co.
Calgon, Inc.
Cochrane Corp.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
General Filter Co.
Infilco Inc.
Johns-Manville Corp.
Northern Gravel Co.
Permutit Co.
Carl Schleicher & Schuell Co.
Stuart Corp.

Filters, incl. Feedwater:
Cochrane Corp.
Dorr-Oliver Inc.
Graver Water Conditioning Co.
Infilco Inc.
Morse Bros. Mchy. Co.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filters, Membrane (MF):
AG Chemical Co.
Millipore Filter Corp.
Carl Schleicher & Schuell Co.

Filtration Plant Equipment:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chain Belt Co.
Cochrane Corp.
Filtration Equipment Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Omega Machine Co. (Div., B-I-F Industries)
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Stuart Corp.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
M. Greenberg's Sons
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
Alco Products, Inc.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Crane Co.
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Stuart Corp.

Fluoride Chemicals:
American Agricultural Chemical Co.

Fluoride Feeders:
Fischer & Porter Co.
Omega Machine Co. (Div., B-I-F Industries)
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
Builders-Providence, Inc. (Div., B-I-F Industries)
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure & Vacuum, Rate of Flow, Sand Expansion:
Builders-Providence, Inc. (Div., B-I-F Industries)
Foxboro Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Morse Bros. Mchy. Co.
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Philadelphia Gear Works, Inc.

Glass Standards—Colorimetric Analysis Equipment:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Hays Mfg. Co.
Mueller Co.

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Rensselaer Valve Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Ion Exchange Materials:
Allis-Chalmers Mfg. Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Hydraulic Development Corp.
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

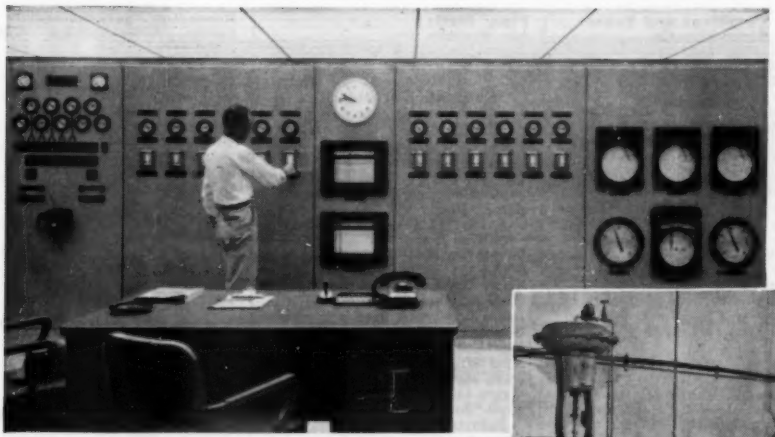
Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Jos. G. Pollard Co., Inc.

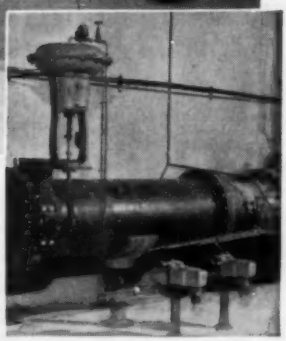
Lime Slakers and Feeders:
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Omega Machine Co. (Div., B-I-F Industries)
Permutit Co.
Wallace & Tiernan Inc.

Magnetic Dipping Needles:
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.



Filter house control panel *puts complete control of this 48-mgd plant in the hands of one man. The plant was designed by Reagan and McCaughan, Consulting Engineers, Corpus Christi.*



In the pipe gallery, *these Honeywell Mercuryless* ***Differential Converter*** *pneumatic transmitters measure loss of head and filter effluent flow. Remotely set Honeywell diaphragm actuators position butterfly valves to hold desired filtering rate.*

One man controls 48-mgd through 12 filters at new Corpus Christi plant

. . . using Honeywell *Filtermatic** System

CENTRALIZED instrumentation, incorporating a Honeywell *Filtermatic* control system, increases efficiency and cuts supervisory work load at the new O. N. Stevens Water Filtration Plant at Corpus Christi, Texas. At his instrument panel, a single operator can see everything he needs to know about the functioning of 12 filters that treat 48 million gallons of water daily. During backwashing, valves are positioned and flow rates adjusted from individual filter consoles. No need to go down to pipe galleries to operate this plant.

Tel-O-Set miniature indicators show rate of flow through each filter, permit individual adjustments of filtering rate set points, and provide continuous indication of filtering rate and desired filtering rate. A 12-point *ElectroniK* instrument records all these flow values on a single wide chart.

Loss of head for each filter, indicated by individual dial gages, is recorded by another 12-point *ElectroniK* instrument. There are also recorders for clearwell level, wash water tank level, plant effluent main pressure, plant effluent flow, and wash water flow.

Honeywell service included application engineering of the control system and complete fabrication, piping and wiring of panels.

A Honeywell field engineer will be glad to talk over your filter plant control, with you and your consulting engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Phila. 44, Pa.—in Canada, Toronto 17, Ontario.

MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

First in Controls

*Trademark of Minneapolis-Honeywell Regulator Co.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Hays Mfg. Co.
Hersey Mfg. Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Worthington-Gamon Meter Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Weil Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Builders-Providence, Inc. (Div., B-I-F Industries)
Foster Eng. Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Weil Machinery & Supply Co.
Worthington-Gamon Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
Infilco Inc.
F. B. Leopold Co.

Paints:
Barrett Div.
Inertol Co., Inc.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.

Pipe, Copper:
American Brass Co.

Pipe, Steel:
Alco Products, Inc.
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.

Pipe Cleaning Services:
Ace Pipe Cleaning, Inc.
National Water Main Cleaning Co.

Pipe Cleaning Tools and Equipment:
Flexible Inc.

Pipe Coatings and Linings:
Barrett Div.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Reilly Tar & Chemical Corp.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
Reed Mfg. Co.
A. P. Smith Mfg. Co.
Spring Load Mfg. Corp.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pipe Vises:
Reed Mfg. Co.
Spring Load Mfg. Corp.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Morse Bros. Mchy. Co.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
Infilco Inc.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Morse Bros. Mchy. Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves; see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
General Filter Co.
Graver Water Conditioning Co.
Permutit Co.

Sodium Aluminate:
Monolith Portland Midwest Co.

Sodium Chloride:
Frontier Chemical Co.

Sodium Hexametaphosphate:
Calgon, Inc.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon, Inc.
Cochrane Corp.
General Filter Co.
Infilco Inc.
Morton Salt Co.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Hays Mfg. Co.
Mueller Co.

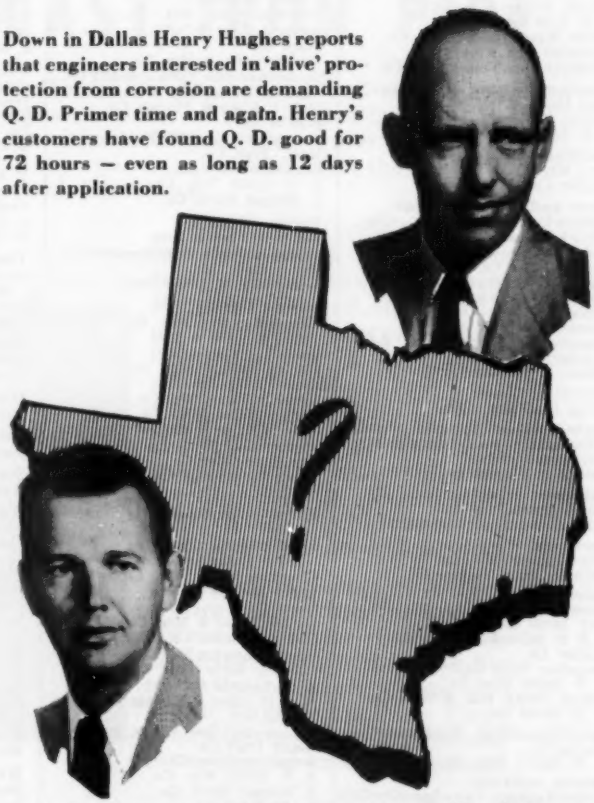
Storage Tanks; see Tanks

Strainers, Suction:
James B. Clow & Sons
M. Greenberg's Sons
Johnson, Edward E., Inc.
R. D. Wood Co.

WHEN IT COMES TO SERVICE

COME TO REILLY

● Down in Dallas Henry Hughes reports that engineers interested in 'alive' protection from corrosion are demanding Q. D. Primer time and again. Henry's customers have found Q. D. good for 72 hours — even as long as 12 days after application.



● Pipeline men in the Houston area are like their contemporaries in other localities — they want good protective coatings and practical suggestions from the manufacturer concerning application procedures. Bill Sandland is ready to supply help at all times.

Reilly COAL TAR PRODUCTS

Reilly Tar & Chemical Corporation
MERCHANTS BANK BUILDING, INDIANAPOLIS 4, INDIANA
Sales Offices in Principal Cities

1209 National City Building, Dallas 1, Texas
Bermac Building, 1401 San Jacinto, P. O. Box 8188, Houston 4, Tex.

Surface Wash Equipment:
Cochrane Corp.
Permutit Co.

Swimming Pool Sterilization:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Omega Machine Co. (Div., B-I-F Industries)
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tanks, Steel:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
Builders-Providence, Inc. (Div., B-I-F Industries)
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Tenoning Tools:
Spring Load Mfg. Corp.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.
S. Morgan Smith Co.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Shower Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Shower Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Large Diameter:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Regulating:
DeZurik Shower Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
Henry Pratt Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
Builders-Providence, Inc. (Div., B-I-F Industries)
Infilco Inc.
Simplex Valve & Meter Co.

Waterproofing:
Barrett Div.
Inertol Co., Inc.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Cochrane Corp.
Dorr-Oliver Inc.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Screens:
Johnson, Edward E., Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite; see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1955 AWWA Directory.

Huntsville, Ala., *Rocket City* U. S. A.

Recognizes 118-Year Service of CAST IRON PIPE

Historic Huntsville, Ala.—rocket and guided missile development center of the U.S.A.—is one of the nation's 60 cities with Cast Iron water mains laid over a century ago. Completed in 1838, they are still giving dependable service.

Modern Huntsville is a thriving city with a "zooming future." Establishment of the Redstone Arsenal and location of many new enterprises have necessitated a major waterworks expansion.

Due recognition of the long and satisfactory service of Cast Iron Pipe in Huntsville was given by its City Council when it purchased 13,000 tons of new Cast Iron Pipe for this project.

Permanence, trouble-free service and savings to taxpayers are the major reasons why municipal engineers in the big majority of other cities also make Cast Iron Pipe first choice for new installations and extensions of existing systems.

* * * * *

Our Company does not manufacture Cast Iron Pipe, but produces quality iron from which quality pipe is made by many of the nation's leading foundries.

WOODWARD IRON COMPANY *Since 1882*

WOODWARD, ALABAMA

The Rockwell "O" -Ring Stuffing Box Assembly

Stops Leaks, Binds, Troubles, Expense

The Greatest Single Advance In Water Meter Construction In Years

Here's another outstanding development from Rockwell Research. It's a sure cure for all the headaches that go with meter stuffing box maintenance. Perfected four years ago, this Rockwell "O"-Ring Stuffing Box assembly has now been thoroughly field tested. *It won't leak; can't bind!* Meters with this construction run more freely, stay accurate longer. Worn spindles are a thing of the past.

Now *all* Rockwell water meters make use of this *exclusive* "O"-Ring design upon which patent application has been made. There's no extra cost for this construction, but a lot of extra satisfaction and value. Ask your Rockwell representative to demonstrate. And be sure to inquire about the use of "O"-Ring stuffing box nuts as interchangeable replacements for stuffing box assemblies in earlier model Rockwell meters.

ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA. Atlanta Boston Charlotte Chicago Dallas Denver Houston Los Angeles Midland, Texas. New Orleans New York N. Kansas City Philadelphia Pittsburgh San Francisco Seattle Shreveport Tulsa. In Canada: Rockwell Manufacturing Company of Canada, Ltd., Toronto, Ontario

Water Treatment, too, needs
INDIVIDUAL DIAGNOSIS

No two water treatment problems are exactly alike. The right solution to each can only be arrived at after a careful study of the local conditions. Variables such as raw water composition, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to fit the job . . . and not vice versa.

One of the Monorake units at New Orleans

New Orleans
LOUISIANA

Completes Expansion Program with 200 MGD Conventional Water Treatment Plant

New Orleans started its water plant expansion program with the installation of twelve Dorrco Hydro-Treator mechanisms . . . six each in two existing basins with the basins operating in parallel at 50 MGD each. This gave the City immediate high-rate softening and clarification capacity for 100 MGD.

It recently completed its program with a conventional treatment plant with 200 MGD capacity. Following chemical pretreatment, clarification is carried out in two rectangular basins which were part of the original plant. Each basin is now equipped with a Dorrco Monorake 106′ 6″ wide with lengths of 477′ and 508′.

If you'd like more information on the complete line of Dorr-Oliver water treatment equipment, write for Bulletin No. 9141 to Dorr-Oliver Incorporated, Stamford, Connecticut.

Hydro-Treator and Monorake T.M. Reg. U. S. Patent Office.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

LEADITE

Trade Mark Registered U. S. Pat. Office

Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%

THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking